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ACOUSTIC MEASUREMENTS OF F100-PW-100 ENGINE OPERATING IN HUSH HOUSE

NSN 4920-02-070-2721

STRUCTURAL INTEGRITY BRANCH
STRUCTURES AND DYNAMICS DIVISION

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G. A. Plzak
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this test program was to measure the acoustic environment in the hush house facility located at Kelly AFB Texas during operation of the F100-PW-100 engine to ensure that engine structural acoustic design limits were not exceeded. The acoustic measurements showed that no sonic fatigue problems are anticipated with the F100-PW-100 engine structure during operation in the hush house. The measured acoustic levels were less than those measured in an existing F100-PW-100 engine wet-cooled noise suppressor, but were increased over that measured during operation on an open test stand. It was recommended that the acoustic load increases

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) measured in this program should be specified in the structural design criteria for engines which will be subjected to hush house operation or defining requirements for associated equipment.

FOREWORD

This effort was performed by the combined efforts of the Structural Integrity and Structural Vibrations Branches, Structures and Dynamics Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. This effort was initiated under JONs 75006017 and ASD08112 and performed in support of the first article hush house testing program at Kelly Air Force Base, Texas. This program was accomplished to assure contract compliance with respect to structural noise levels. The work was requested by the Deputy for Propulsion, Directorate of Propulsion Logistics, Tactical Engines ILS Office (Ref 1). Mr D. Edmunds and later Ms. L. Roch and Ms. L. Dow (ASD/YZFL) were the focal points for this activity. Mr. G. E. Sherwood was the point of contact at Kelly AFB.

The work was performed by Mr. V. R. Miller of the Structural Integrity Branch and Mr. G. A. Plzak and Ms. J. M. Chinn of the Structural Vibrations Branch from May 1981 to September 1981. The authors wish to extend their appreciation to Messrs. M. A. Hart and L. P. Vaughn who assisted with the data acquisition and reduction. Special acknowledgement is due Mmes. J. Tope, Mia Arnold, K. Brink and D. Cardone for typing the manuscript.

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I. INTRODUCTION

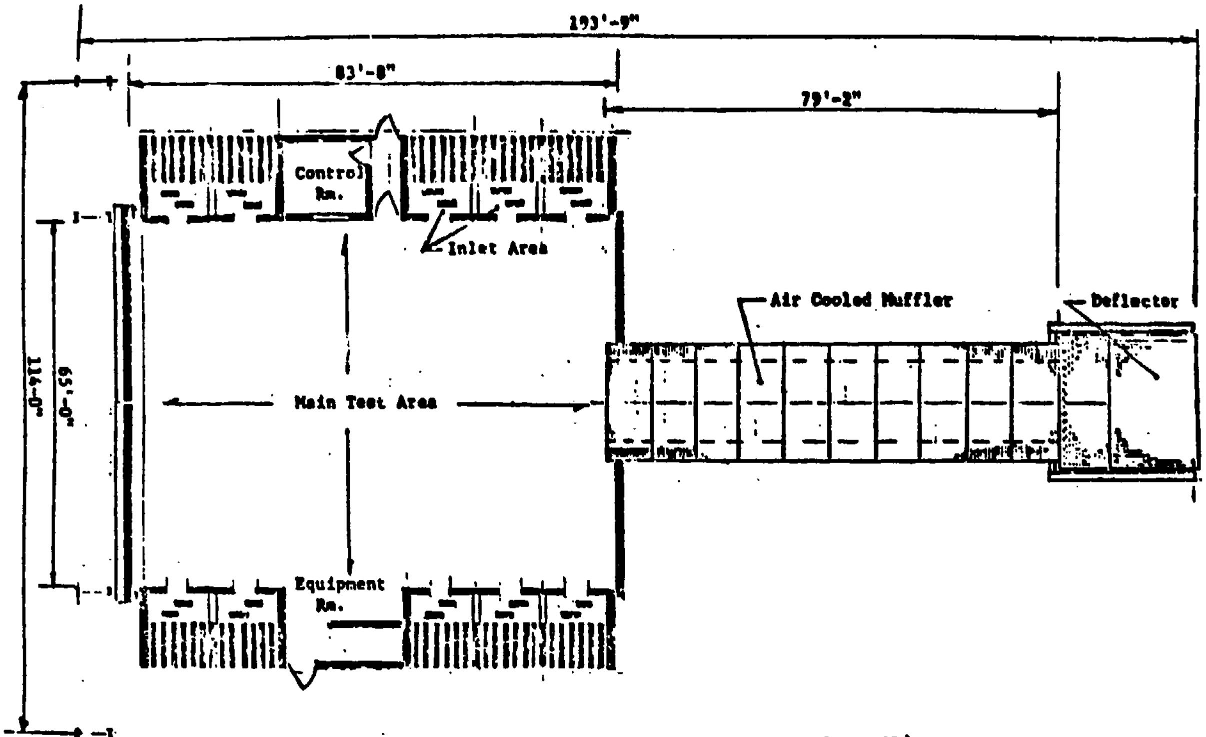
An Aero-System Engineering (ASE) hush house, NSN 4920-01-070-2721, was constructed at Kelly AFB, Texas. This hush house is an air cooled noise suppressor system (NSS) which completely encloses installed and uninstalled engines for environmental control purposes during ground run-up. The NSS is compatible with all types of USAF fighter aircraft. Enclosing an engine in such a manner increases the sound pressure levels on the engine structure. Increasing these levels can decrease the fatigue life of the engine and compromise its structural integrity if structural acoustic design limits are exceeded. Therefore, qualification of the ASE hush house for the F100-PW-100 engine with respect to acoustics is essential. The Deputy for Propulsion requested (Ref. 1) the Structures and Dynamics Division of the Flight Dynamics Laboratory to perform a test program to measure the acoustic environment with the F100-PW-100 operating in the ASE hush house. The purpose of this effort was to ensure that the acoustic environment within the hush house did not exceed structural design limits and to identify potential problems with the F100-PW-100 engine structure.

A brief description of the hush house is contained in Section II. Section III of this report describes the test, data acquisition, and data reduction procedures used during this program. A discussion of the results is included in Section IV. The conclusions determined from the program are given in Section V with recommendations shown in Section VI. Appendix A shows photographs taken at the test site to document microphone locations, engine orientation, etc. Data reduced from the measurements are included in Appendix B.

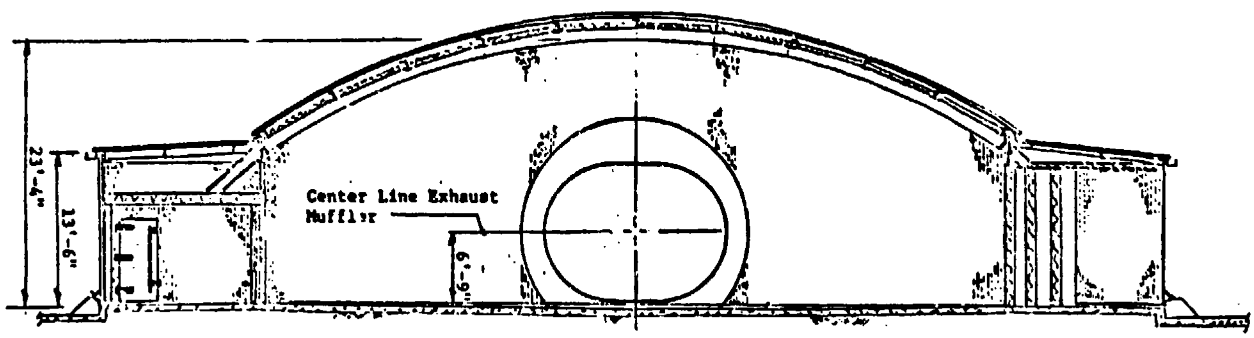
II. DESCRIPTION OF HUSH HOUSE

The hush house which was used during this program is shown in Figure 1. This structure consists of a sound-absorbent hangar with dimensions of approximately 84 by 65 feet (25.6 by 19.8 meter). The surfaces of the hangar were covered with approximately 10,500 square feet (975.5 m^2) of absorbing panels, 4 inches (10.2 cm) thick with a 20 gauge (0.093 cm) perforated face sheet (304 stainless steel), 16% open area and filled with 4.8 lb/ft^3 (76.9 kg/m^3 fiberglas. The fiberglas was wrapped in a fiberglas cloth. The hangar fully encloses both aircraft and uninstalled engines during ground run-up. The hush house is suitable for testing aircraft of any size and configuration which are geometrically compatible. The engines which may be tested in this facility are positioned on a thrust stand and restrained by embedments during engine run-up. This hush house is also air-cooled which eliminates the need for a water spray system in the muffler. Water spray has a deleterious effect on air quality and acoustic absorptive treatments.

The inlet area allows large air flows and low air velocity past the engine under test. The intake system has a bird screen. Downstream of the birdscreen are sound-absorbent baffles arranged as a labyrinth. The engine jet exhausts into a muffler. Large volumes of air are pumped through the intake system, over the engine, and into the muffler to cool the engine exhaust. The muffler is made in sections, each of which consists of several chambers. The inner shell is made of perforated and corrugated 321 stainless steel with 4.5 lb/ft^3 (72.1 kg/m^3) of Basalt wool fill, 4 inches (10.2 cm) thick around the shell. The exhaust gases leaving the muffler are directed vertically by a deflector.



Plan View



Front Elevation

FIGURE 1 Layout of Hush House

III. TEST, DATA ACQUISITION, AND DATA REDUCTION PROCEDURES

The measurements were conducted at Kelly AFB, Texas on 11 June 1981, with the F100-PW-100 engine (S/N 680253) operating in the hangar area of the hush house. The different test runs performed are identified in Table 1. The tests were made with the hangar doors closed. All data were recorded once the engine had stabilized. Estimates of typical engine data are also shown in Table 1. Table 2 lists the surface meteorological conditions during data acquisition.

The basic transducers used during the test program were located as shown in Figure 2. The test instrumentation consisted of 7 Gulton Industries Model MVA2100 5/8 inch (1.6 cm) microphones. Six of the microphones shown in Figure 2 were at the engine centerline plane. One additional microphone was placed at the top of the hush house deflector.

The test procedures which were used were as follows:

1. Install the F100-PW-100 in the hush house hangar area and locate microphones.
2. Calibrate all data recording instrumentation.
3. Record ambients prior to test runs.
4. Operate engine for 20-25 seconds at each of the conditions shown in Table 1.
5. Edit and review data tapes for quality.
6. Repeat any test condition shown to be deficient from step (5).

The Flight Dynamics Laboratory's mobile data acquisition van contained the signal conditioning electronics and tape transports used for this test program. A block diagram of the instrumentation is shown in Figure 3. Landlines carry the data signal from each microphone to the van. The signal conditioning equipment is capable of producing either attenuation

TABLE 1 Summary of Test Runs and Estimated Parameters for F100-PW-100 Engine

RECORD NUMBER	ENGINE POWER SETTING	EXIT VELOCITY (ft/sec)/(m/sec)	THRUST (lb_f)/(nt)	EXIT TEMPERATURE (°R)/(°C)
27	Military	2100/640	14,100/ 62,717	1440/527
28	Max. A/B	3411/1040	23,900/ 106,307	3670/1766

TABLE 2 Meteorological Conditions

Temperature	74°F/23°C
Bar. Pressure	29.085 in. Hg./73.9 cm Hg.
Rel. Humidity	90%
Wind	
-Speed	7 knots/13 km/hr
-Direction	0 deg.

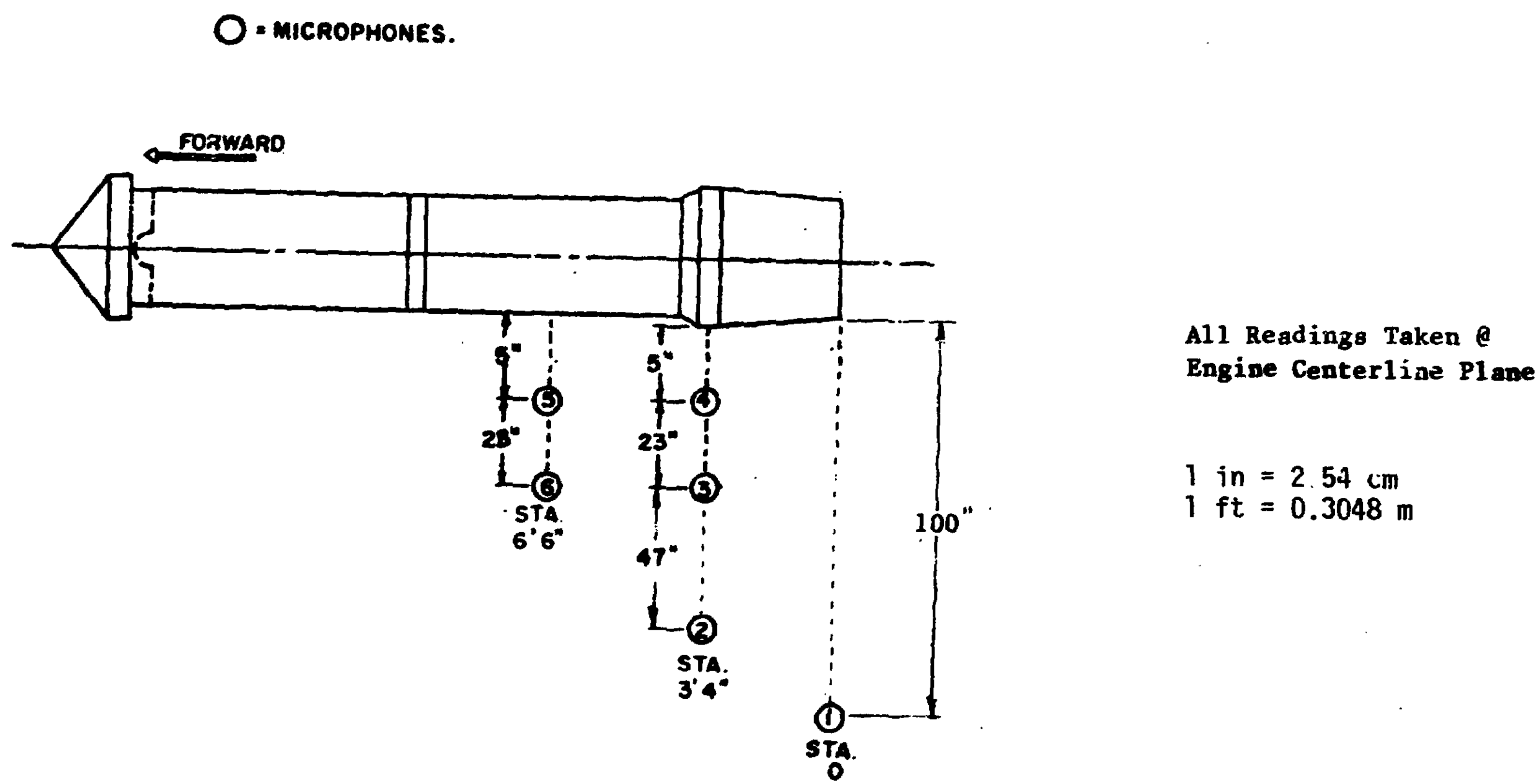


FIGURE 2 F-10C PW-100(3) Engine acoustic instrumentation

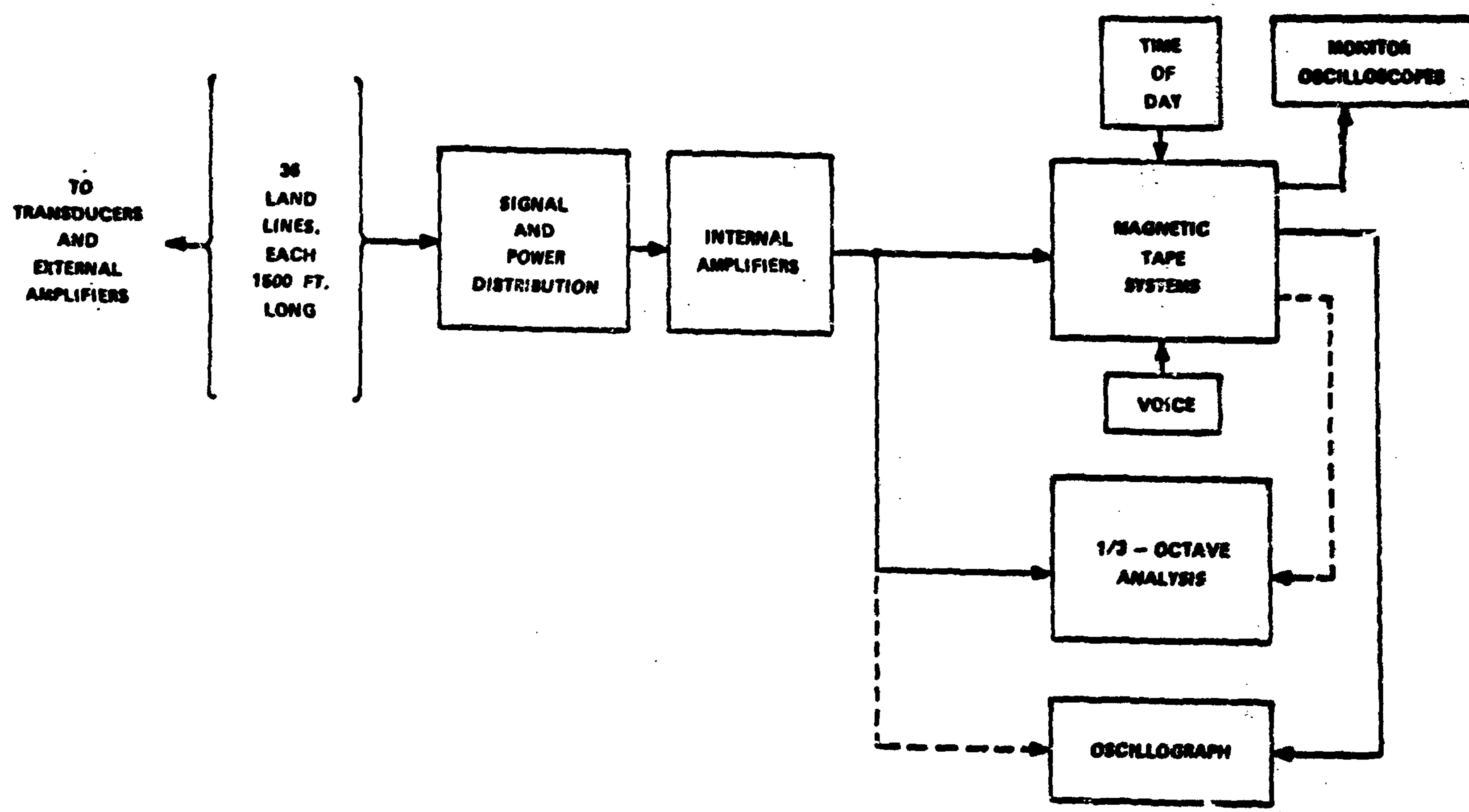


FIGURE 3 Schematic of Data Acquisition System

or amplification in 10 dB steps over the range -10 dB to +60 dB. The tape recorders used were Honeywell Model 96 frequency modulation (FM) systems. A time code was produced by a Systron-Donner 8350 time code generator and recorded on one channel of both magnetic tape recorder/reproducers.

The microphones were calibrated by means of a Bruel and Kjaer Type 4220 pistonphone. The magnetic tapes which recorded the data from the tests were played back in the laboratory at Wright-Patterson AFB on the Honeywell 96 record-reproduce system. All analyses were obtained using a General Radio 1921/1926 one-third octave band analyzer interfaced with an ITI 4900 A/D system. All analyses were processed by a Raytheon 704 computer interfaced with a Gould 4800 high speed plotter. Figure 4 shows a block diagram of the overall data reduction process.

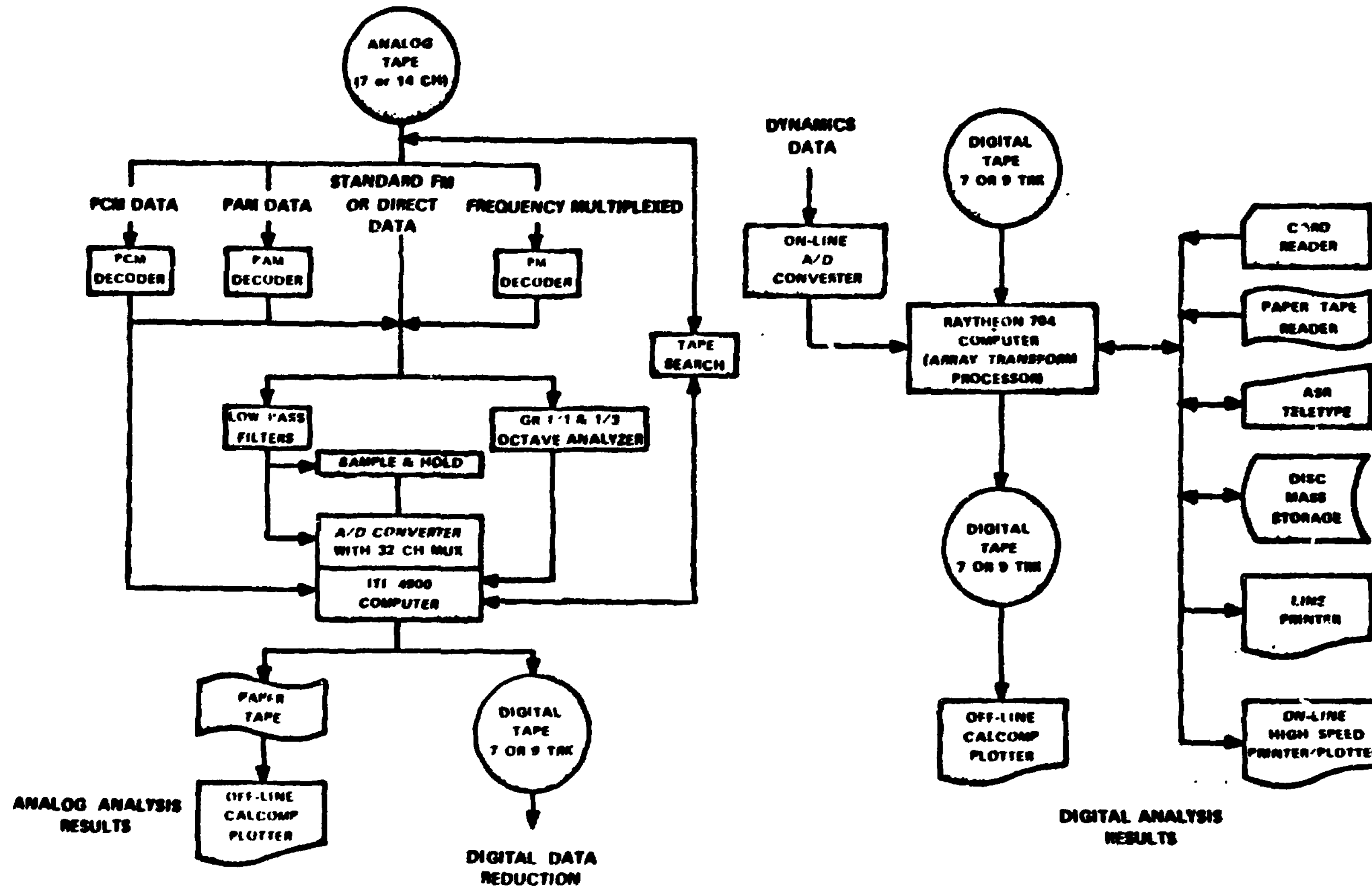


FIGURE 4 Data Reduction Process Diagram

IV. DISCUSSION OF RESULTS

The noise measurements were acquired to verify that maximum allowable engine aft structure noise levels were not exceeded. Six microphones (Figure 2) were located around the F100-PW-100 engine to obtain the maximum sound pressure levels. The levels which should not be exceeded at microphone locations 4 and 5 are reported in several places (Ref 2 and 3) and shown in Table 3. Levels much greater than those shown in this table could cause sonic fatigue problems with engine structure. By examining the limits on the engine and comparing them to the measured sound pressure levels during maximum afterburner (A/B) for microphones 4 and 5, it can be seen (Figure 5) that the measured data are less than the limits and that, as a result, no problems are anticipated with the engine structure.

The octave band criteria presented above are based on the assumption that the distribution of acoustic energy in an octave band is reasonably constant and does not contain discrete frequency peaks. A more meaningful result which does not depend on this assumption can be obtained by directly comparing measured spectrum levels to structural design criteria. Establishment of these design criteria was an evolutionary process. F100-PW-100 engines as operated in test cells during early developmental testing experienced cracks due to high acoustic levels. These production test cells were modified by installation of sound absorbing materials to their interior until the cracking ceased. The acoustic level was then measured and established as a limit. The structural design level which was established was 125 dB spectrum level, and the recommended level was 123 dB spectrum level (Ref. 4). These limits are compared with the measured data during

TABLE 3 Sound Pressure Level Limits (dB ref. 0.00002 Pascal) on F100-PW-100 Engine

	Octave Band Center Frequency - Hz							
	63	125	250	500	1000	2000	4000	8000
Engine	134	141	145	148	150	152	158	155

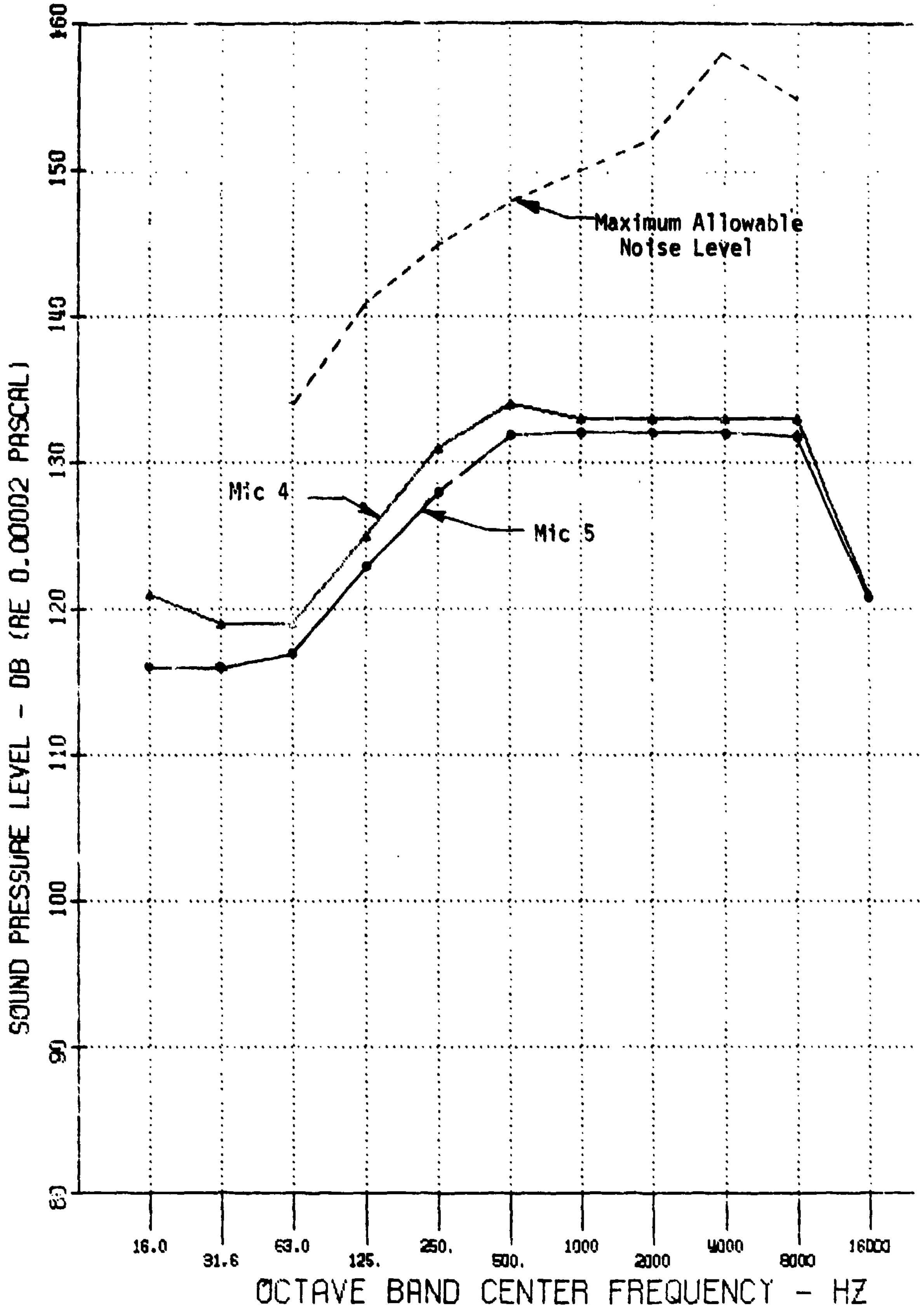


FIGURE 5 Comparison of Sound Pressure Levels Measured During Maximum Afterburner (Record Number 28) and Maximum Allowable Noise Levels on F100-PW-100 Engine Structure

maximum A/B for microphones 4 and 5 in Figure 6. The reader should note that the recommended and structural design levels as plotted are based on one hertz bandwidth while the measured data are plotted as 1.27 hertz bandwidth. The difference resulting from bandwidth difference is quite small (approximately 1 dB) and is considered negligible in this analysis. The data for microphones 4 and 5 are at least 10 dB below the limits. As stated above, no problems are anticipated with the engine structure with respect to acoustic levels.

Figure 7 shows the one-third octave band sound pressure levels measured for microphone 4 during maximum afterburner operation. Also plotted in this figure are measured data from a location similar to microphone 4 in an A/F32T-2 noise suppressor (Ref 5) and during ground run-up on an open test stand (Ref 6). The A/F32T-2 is a demountable noise suppressor system which is water-cooled and has been used for ground run-up of the F100-PW-100 engine. Note that the hush house data are 2-4 dB less than the A/F32T-2 data below 100 hertz and 8-15 dB less above 100 hertz. Similar statements can also be made about microphone 5. Comparing the hush house data with that measured during ground run-up on an open test stand shows 1-6 dB sound pressure level increases between 80 and 500 hertz in the hush house. Since there is an increase in acoustic loading on the structure in this frequency range, this could be important from a sonic fatigue and structural response standpoint. Operation of the engine in the hush house results

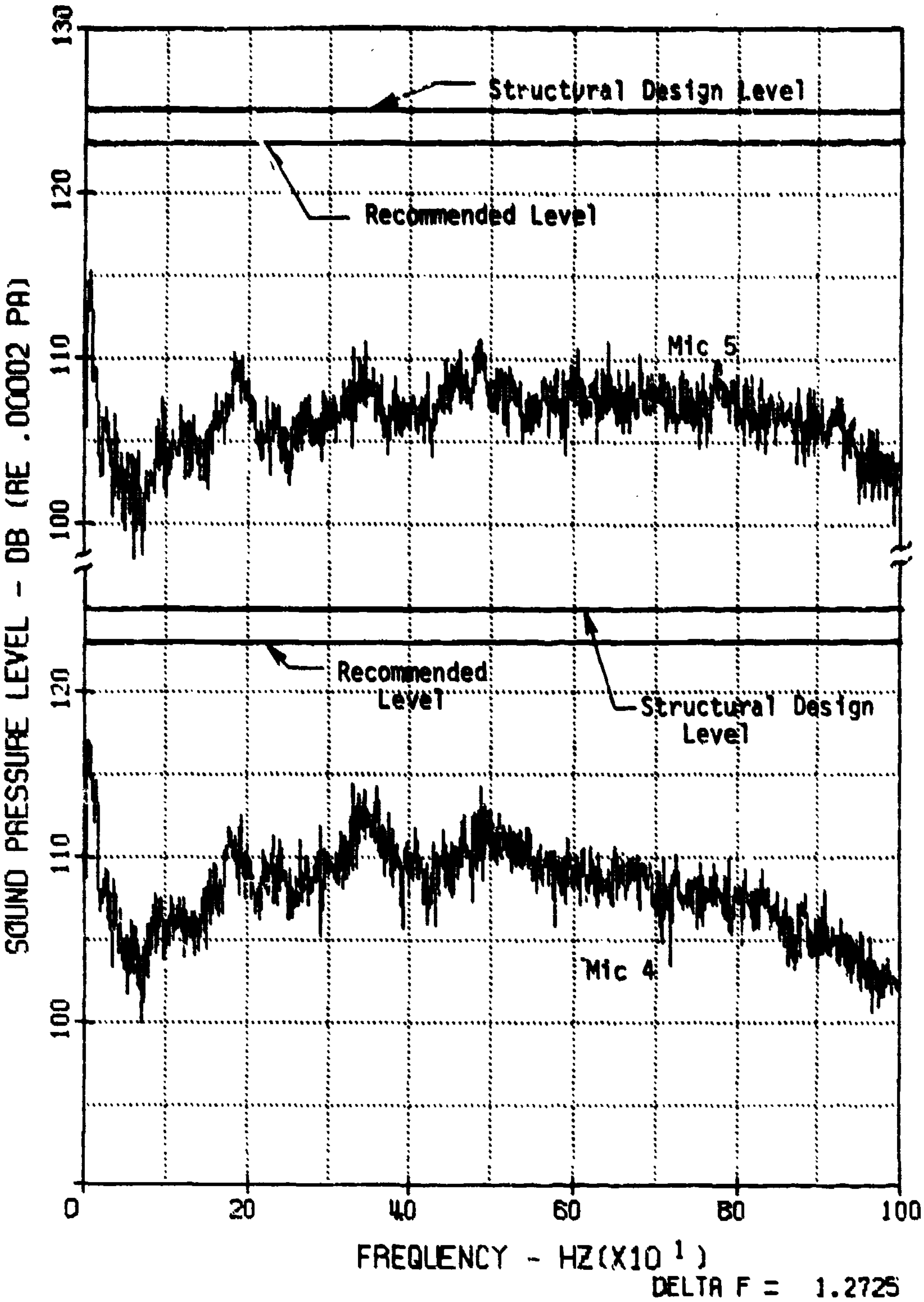


FIGURE 6 Comparison of Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House During Maximum Afterburner and Allowable Noise Levels

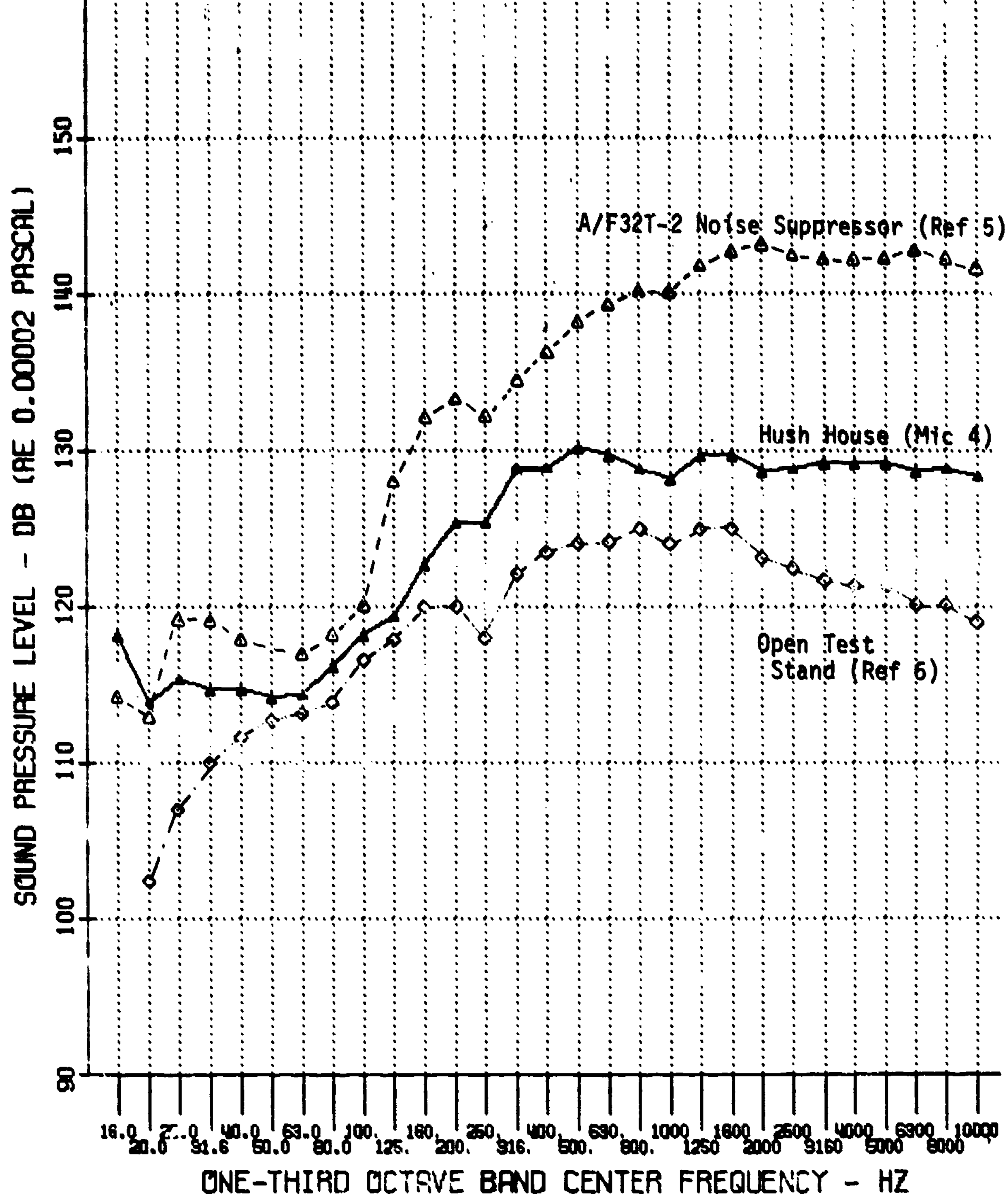


FIGURE 7 Comparison of One-third Band Sound Pressure Levels Measured During Maximum Afterburner in Hush House, A/F32T-2 Noise Suppressor, and Open Test Stand

in increased acoustic loads and correspondingly increased dynamic stresses. These load increases should be specified in the structural design criteria for engines subjected to hush house operation.

V. CONCLUSIONS

1. No structural damage due to sonic fatigue is anticipated with the F100-PW-100 engine structure during operation in the hush house hangar area at maximum afterburner power.

2. The sound pressure levels measured around the F100-PW-100 engine are 2-4 dB less below 100 hertz and 8-15 dB less above 100 hertz than those measured in the A/F32T-2 water-cooled noise suppressor.

3. Measured sound pressure levels in the hush house are greater than those measured during ground run-up on an open test stand. The increases of 1-6 dB between 80 and 500 hertz could be important from a sonic fatigue and structural response standpoint.

VI. RECOMMENDATIONS

The acoustic load increases measured in this program should be specified in the structural design criteria for engines which will be subjected to hush house operation.

APPENDIX A: PHOTOGRAPHS OF TEST SET-UP

Some of the photographs which were taken at the test site are included here. These photographs will serve to give the reader a better idea of where transducers were located, how the engine was positioned in the hush house, etc. These photos were furnished courtesy of the Base Photography Branch at Kelly AFB, Mr. M. A. Hart of AFWAL, and Mr. R. J. Reilly, consultant to ASE, Inc.

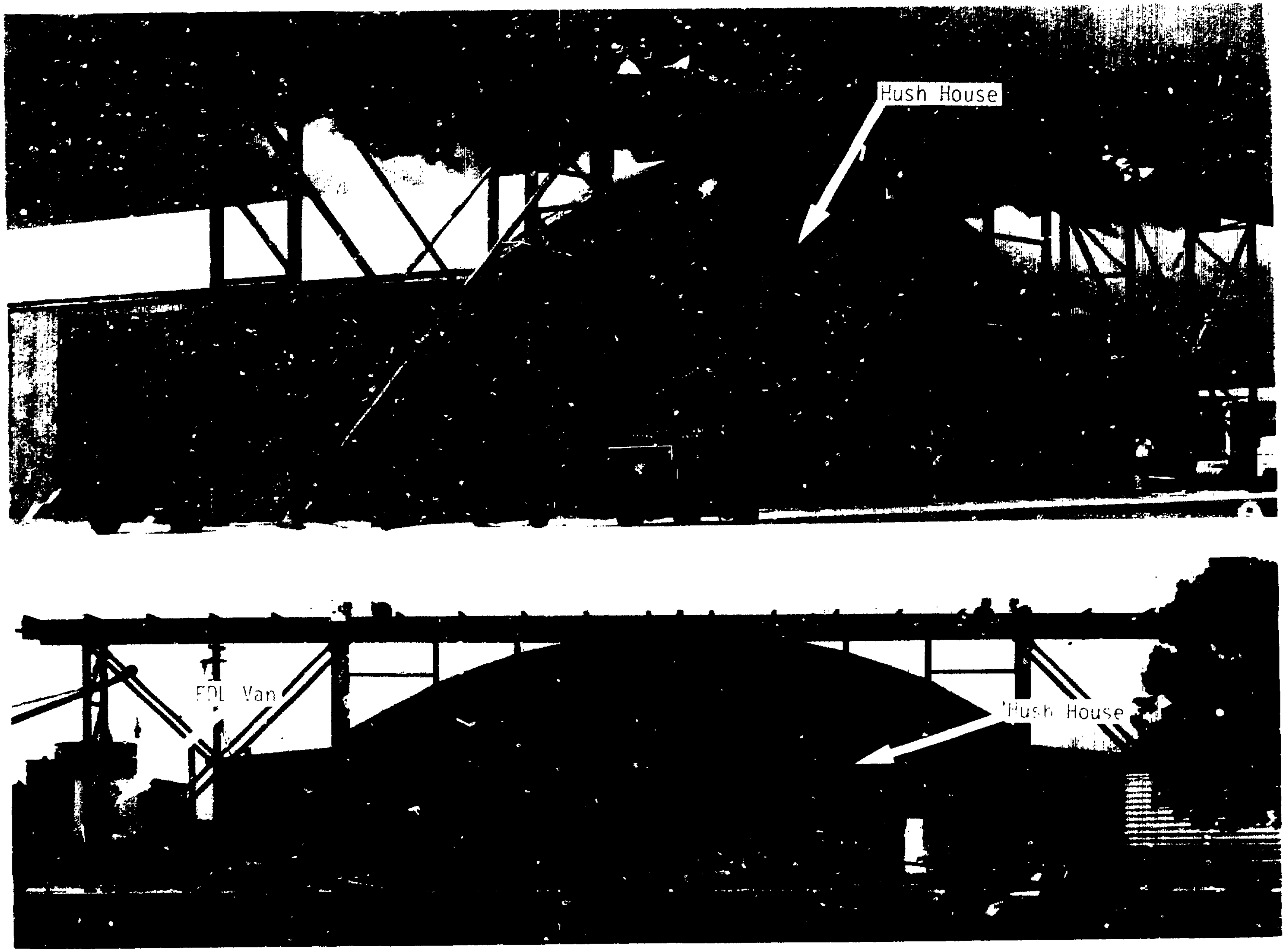


FIGURE A1 Location of FDL Mobile Data Acquisition Van Next to Hush House

FIGURE A2 Location of Microphone 25 Next to Hush House Deflector

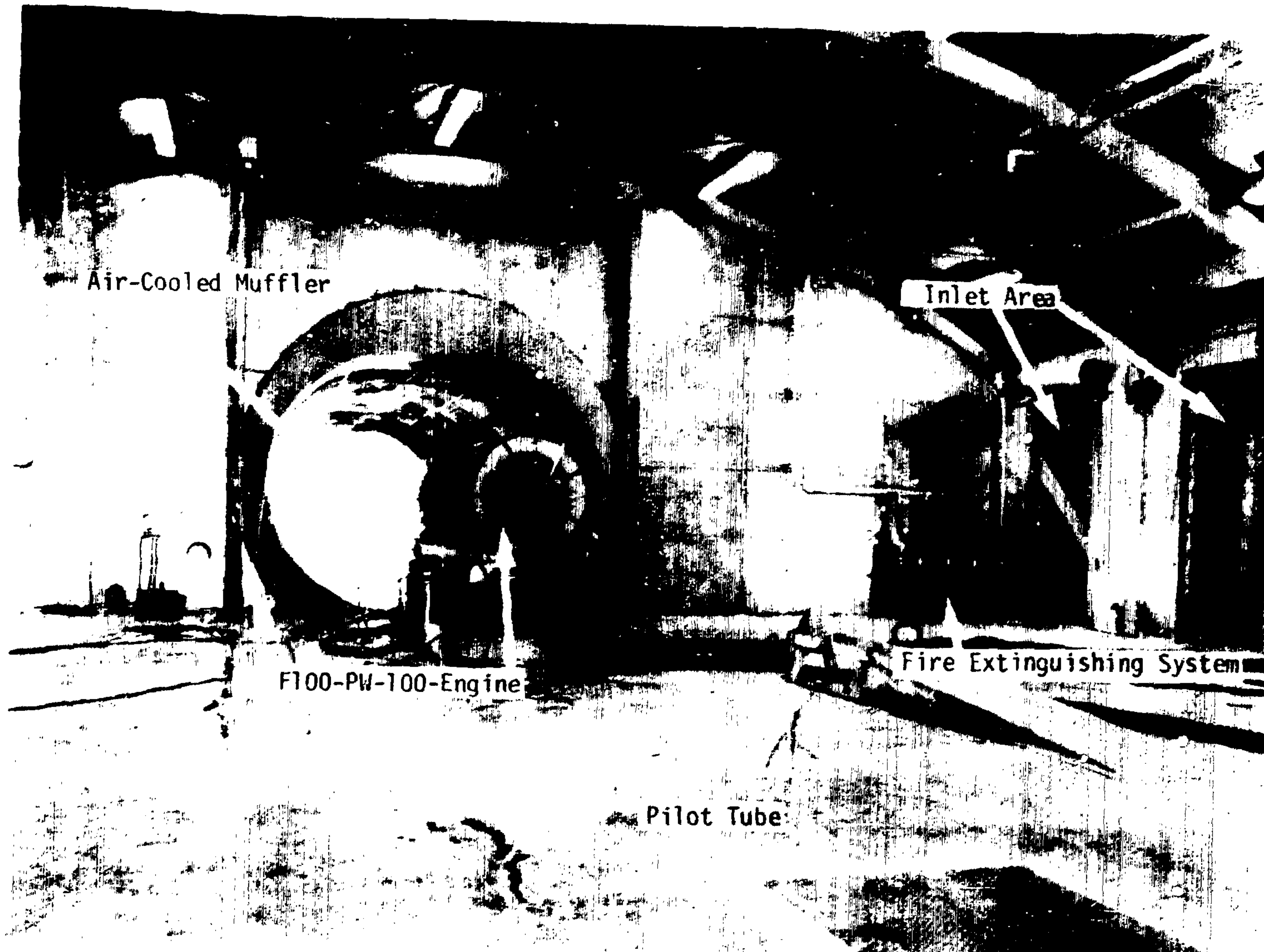


FIGURE A3 Location of F100-PW-100 Engine in Hush House.

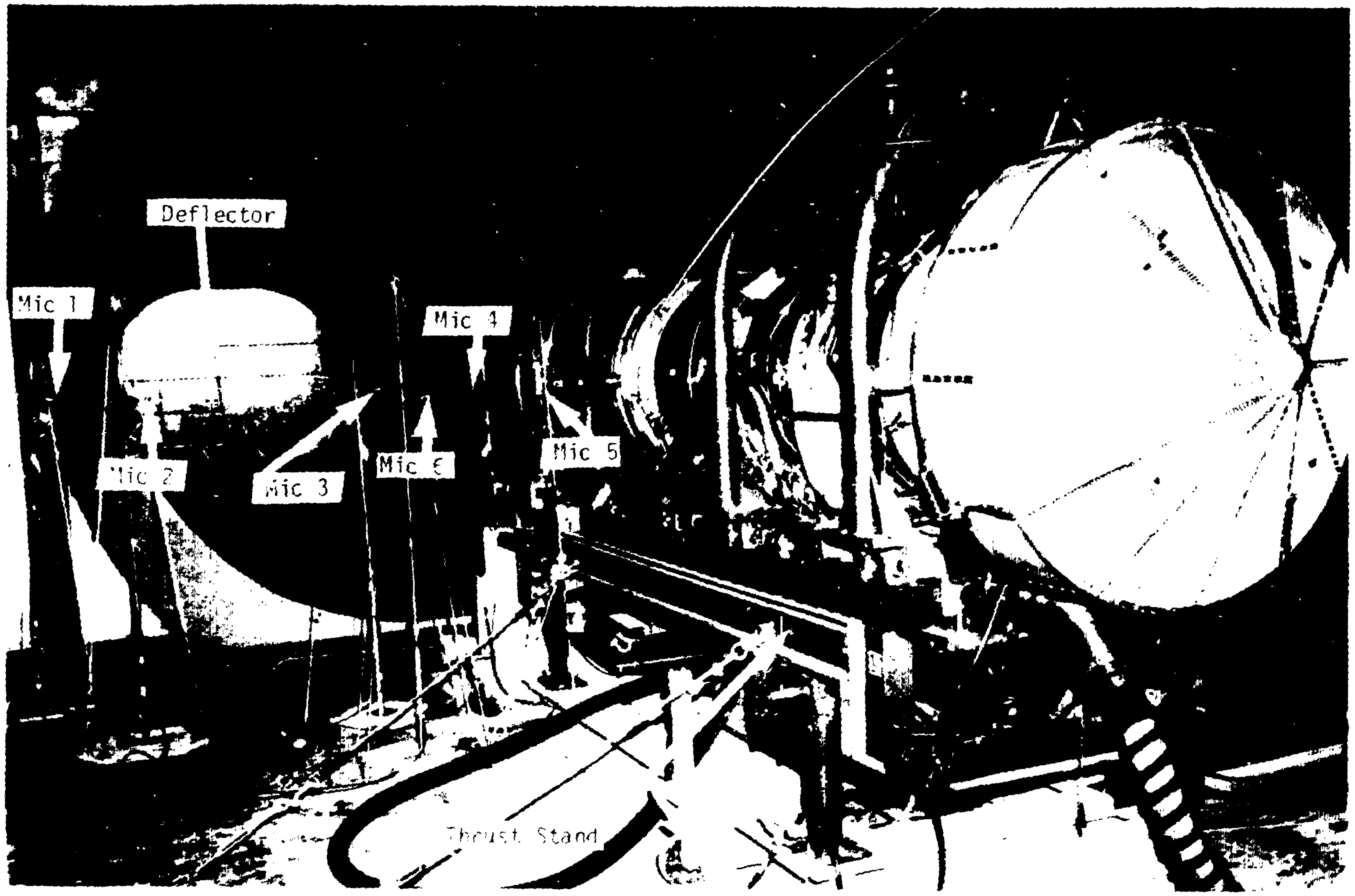


FIGURE [illegible] Location of Microphones 1-6 Near F100-PW-100 Engine.

APPENDIX B. REDUCED DATA

The data which were recorded and analyzed from the test and identified in Table 1 are included here. The octave band sound pressure levels for the microphones are shown in Figures B1 through B6 for Record Numbers 27 and 28. Corresponding one-third octave band levels for the same microphones are shown in Figures B7 through B12 for Record Numbers 27 and 28. A-weighted one-third octave band spectra for five microphones and Record Numbers 27 and 28 are in Figures B13 through B17. Narrowband (1.27 Hertz) spectra for Record Numbers 27 and 28 are shown in Figures B18 through B28. The data for the microphone located at the hush house deflector were saturated with 60 cycle noise and could not be used.

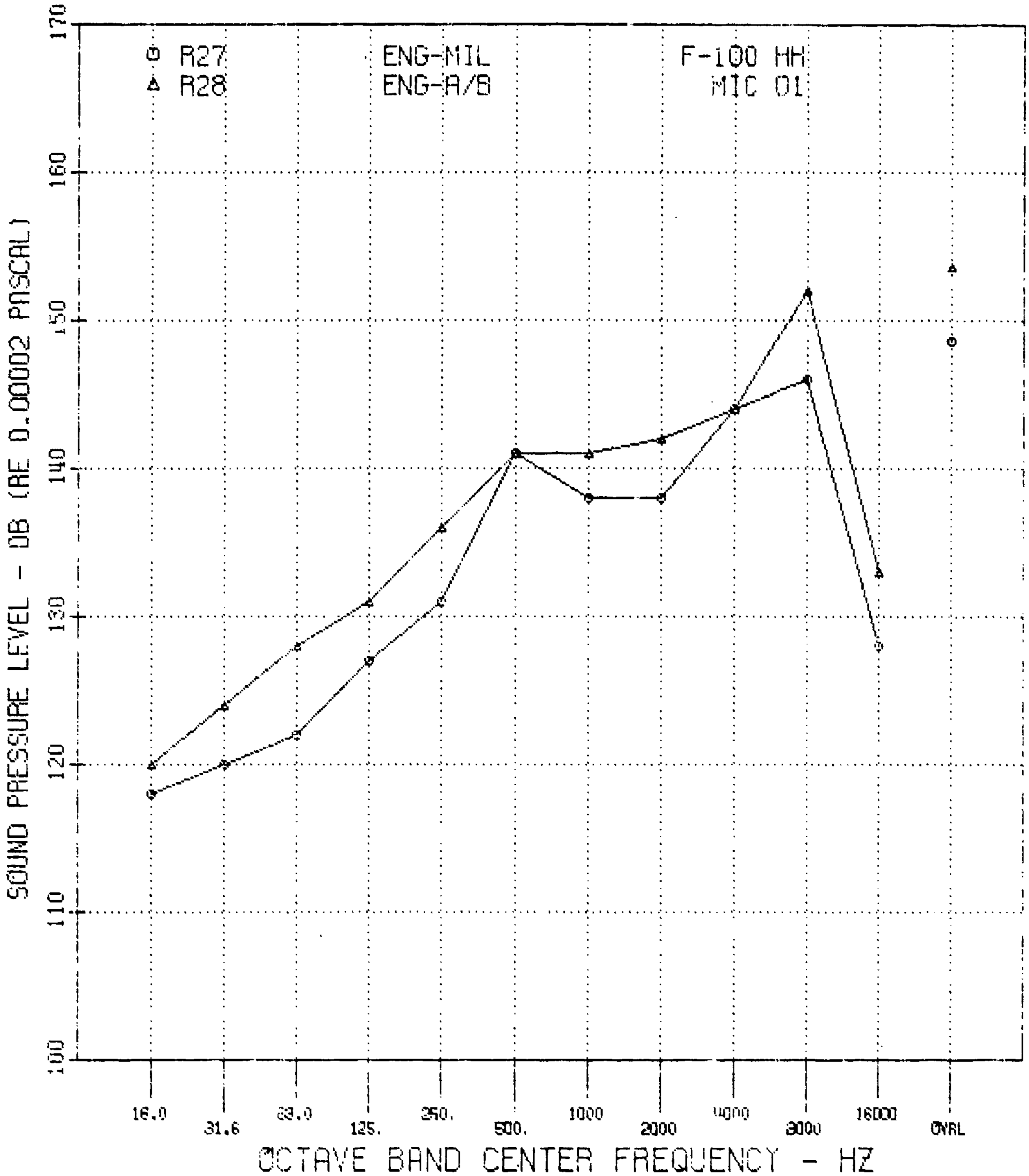


FIGURE B1 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 1.

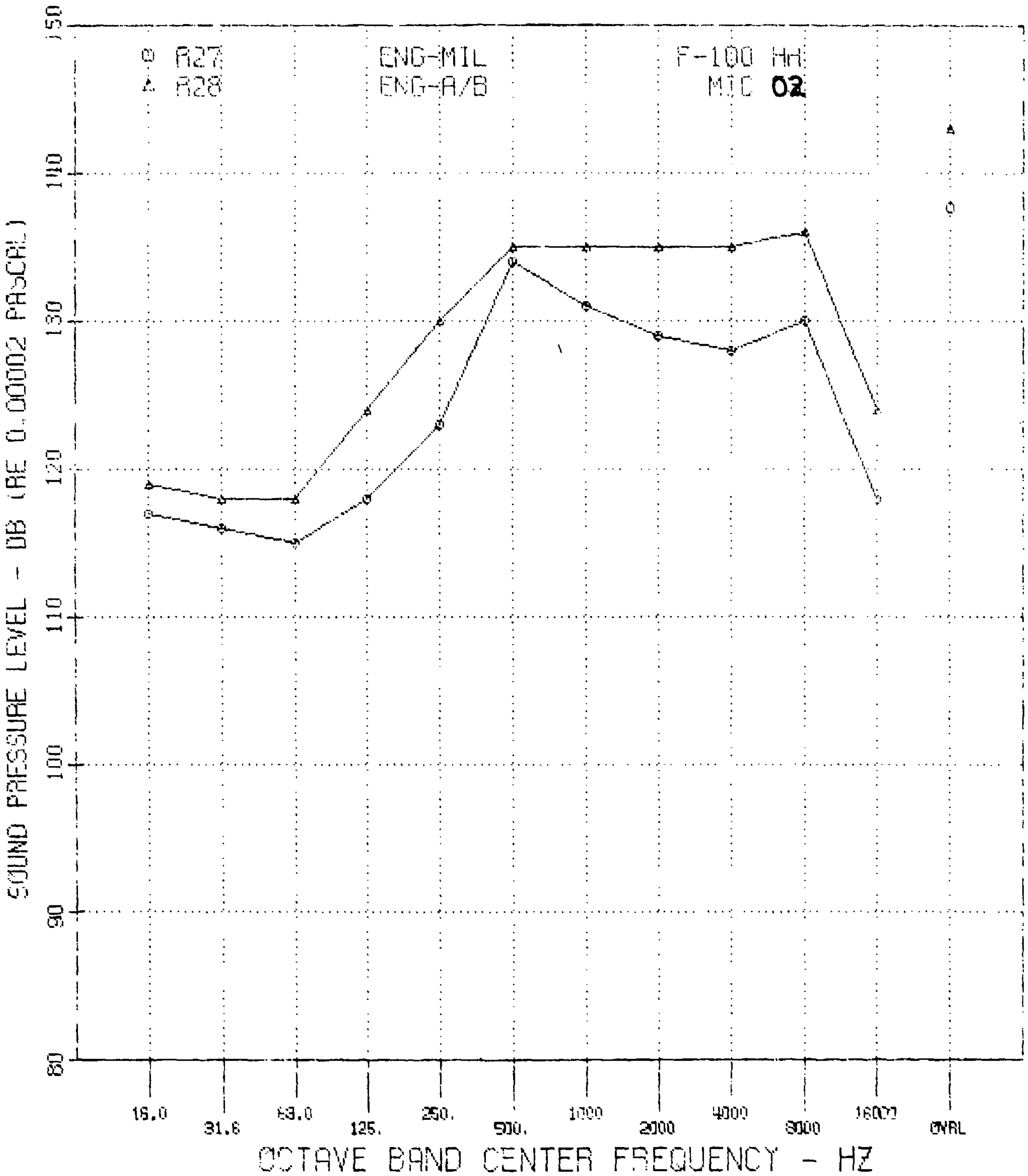


FIGURE B2 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 2.

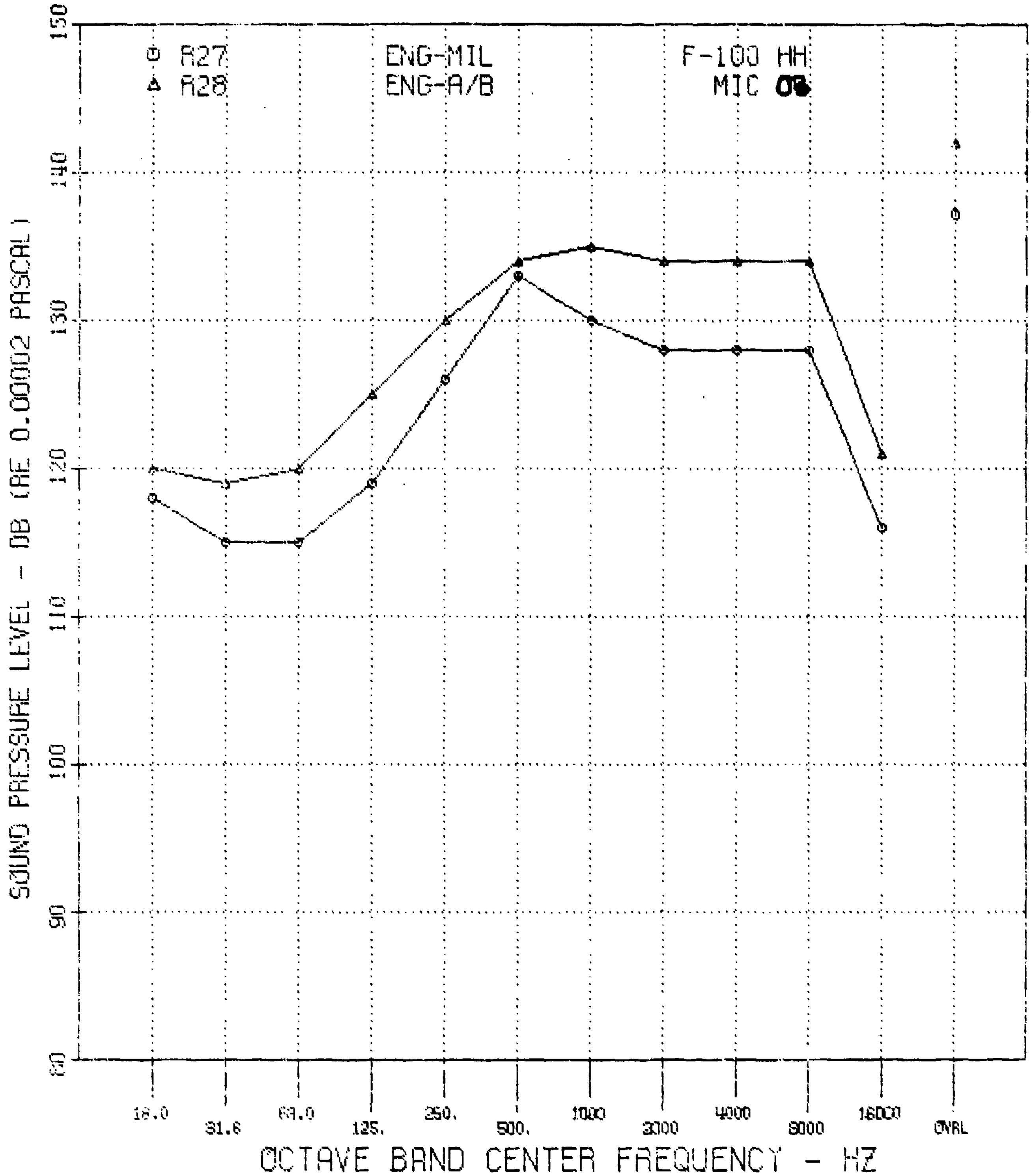


FIGURE B3 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 3.

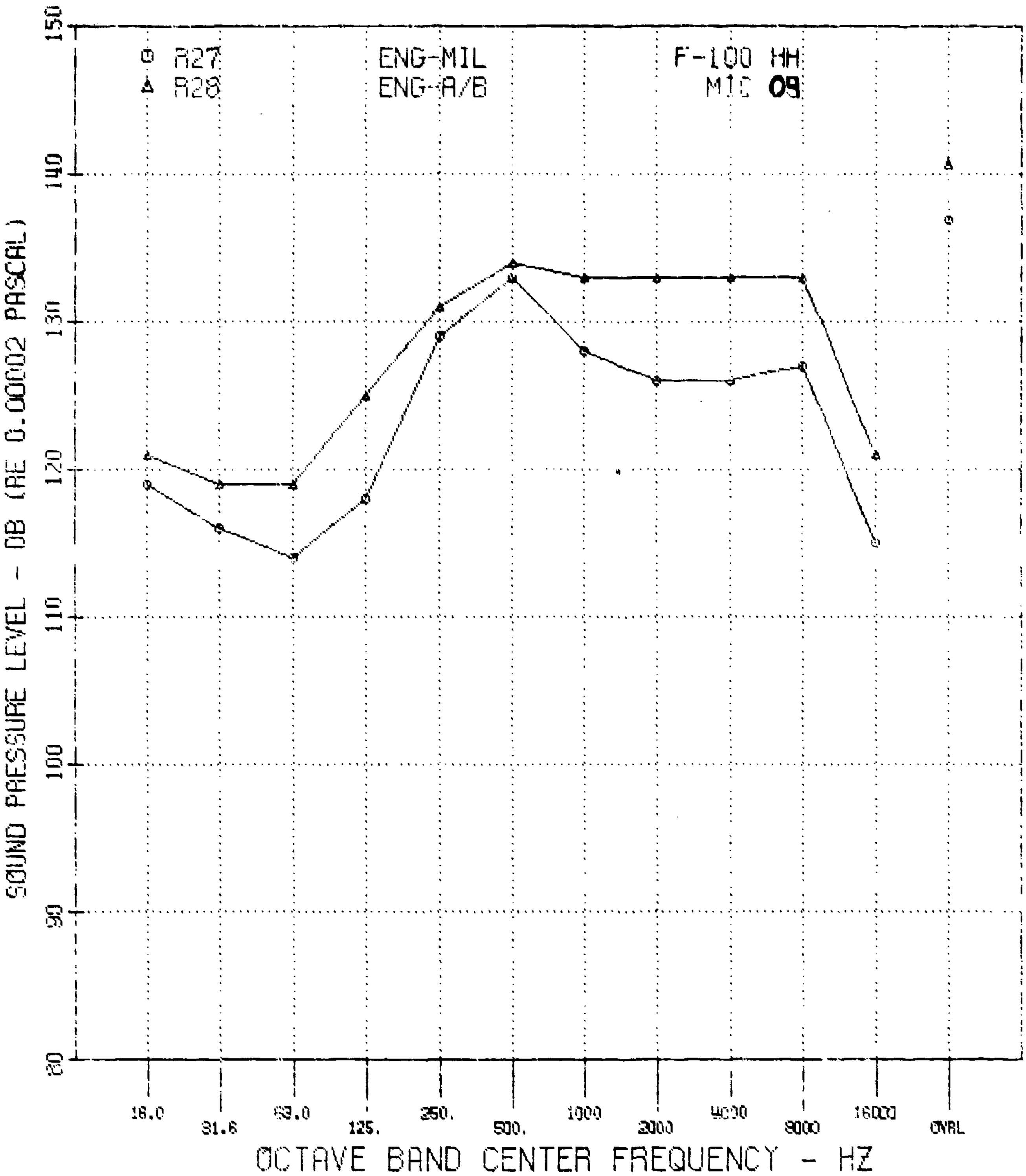


FIGURE B4 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 4.

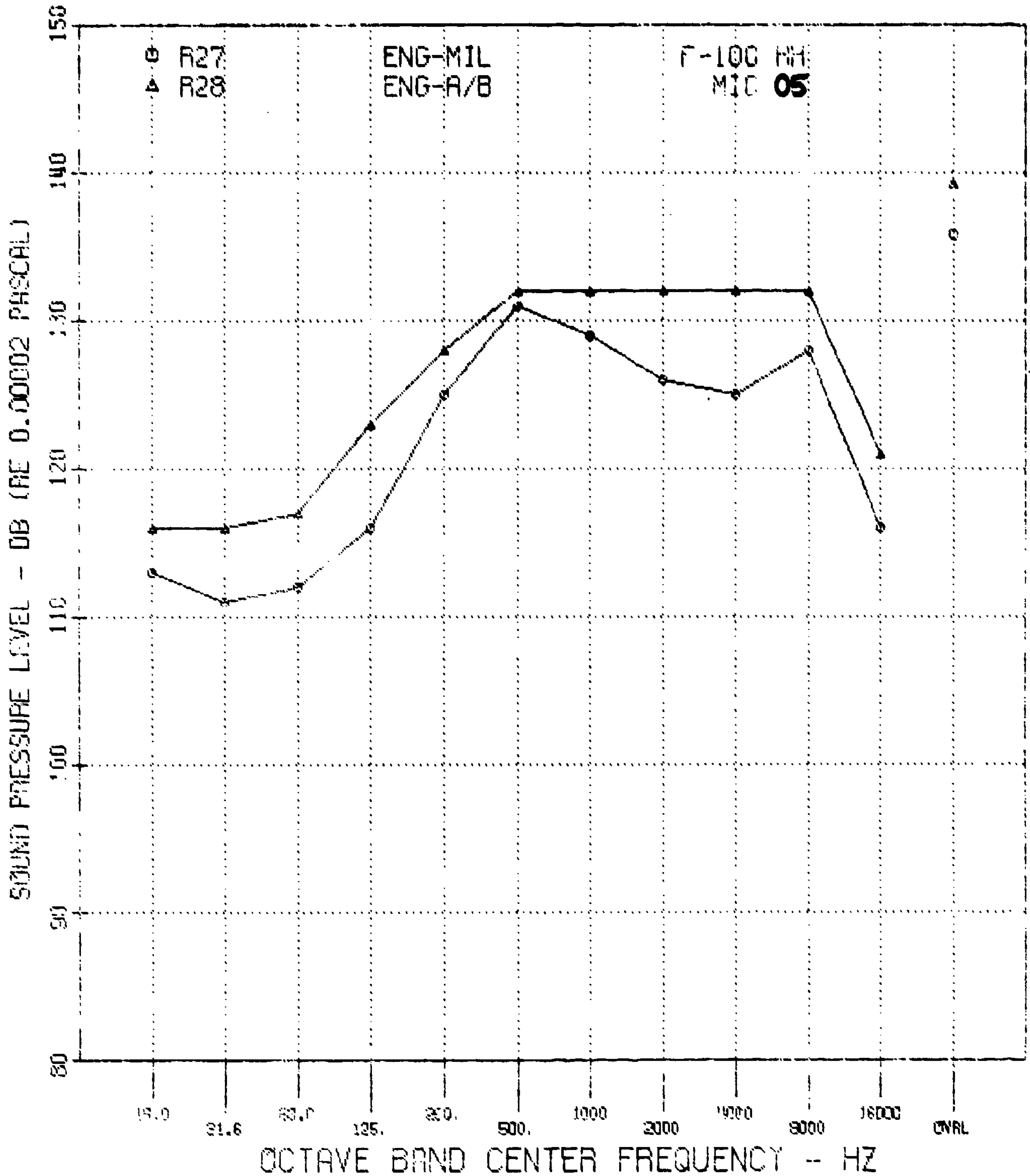


FIGURE B5 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 5.

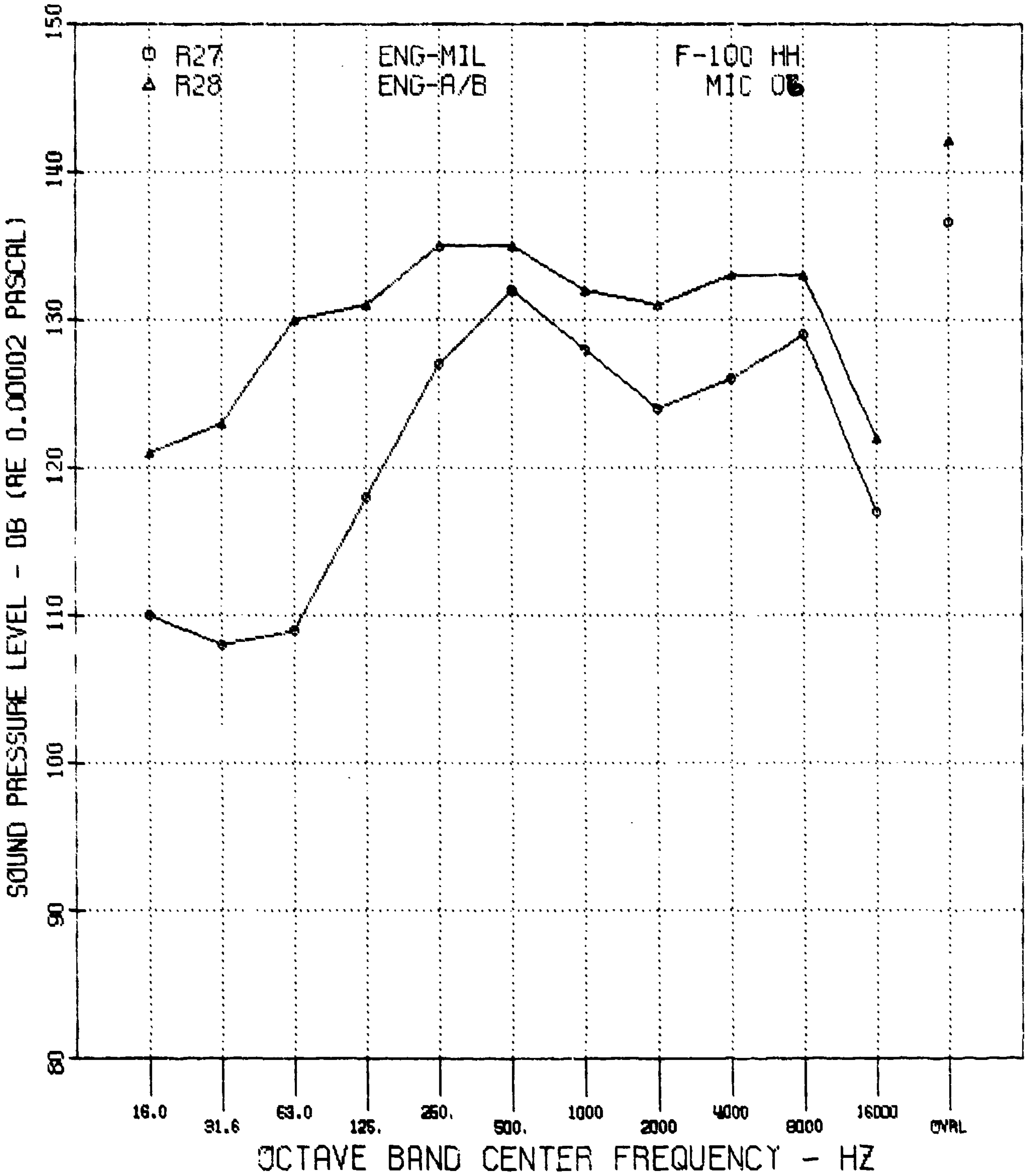


FIGURE B6 Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 6.

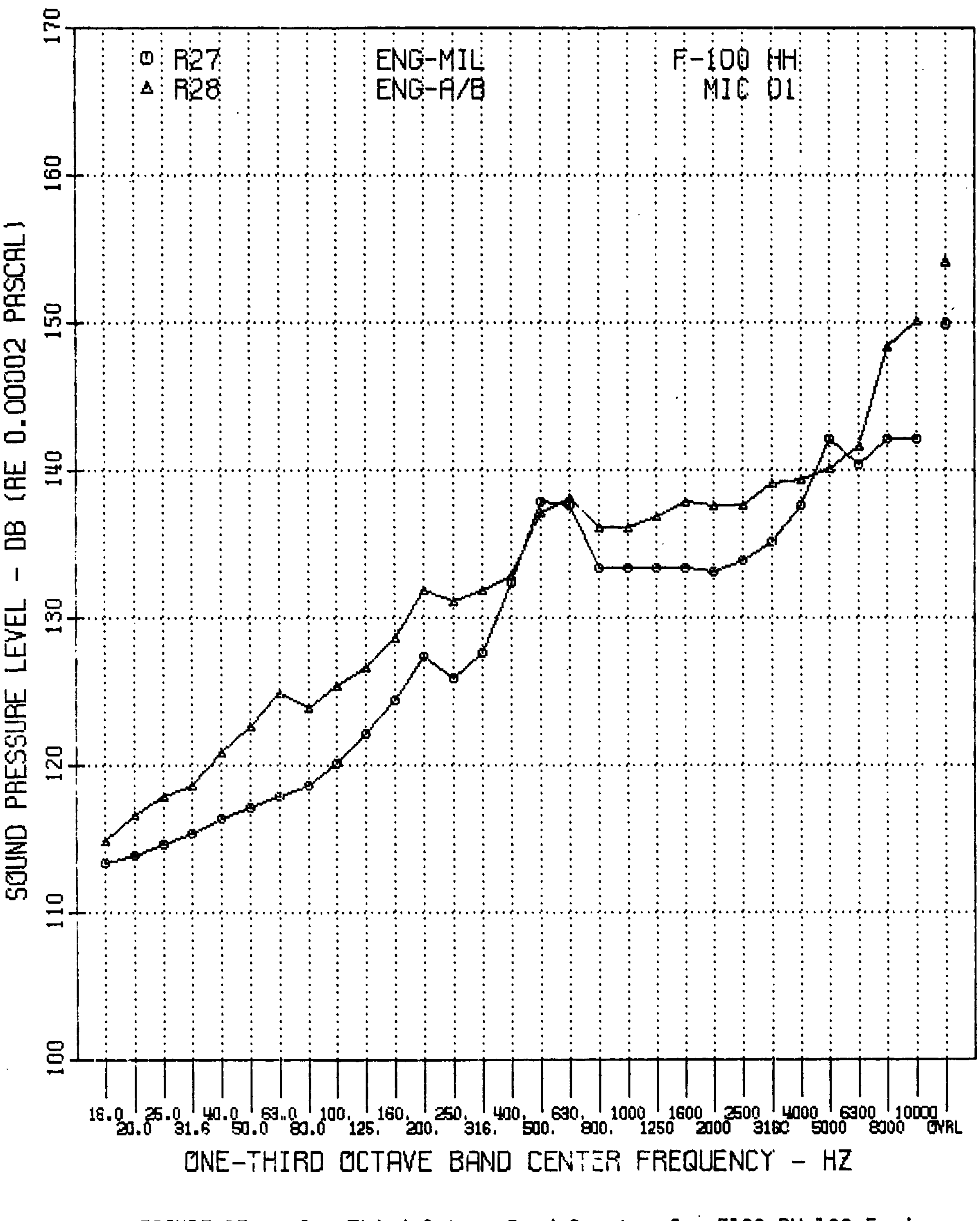


FIGURE B7 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 1.

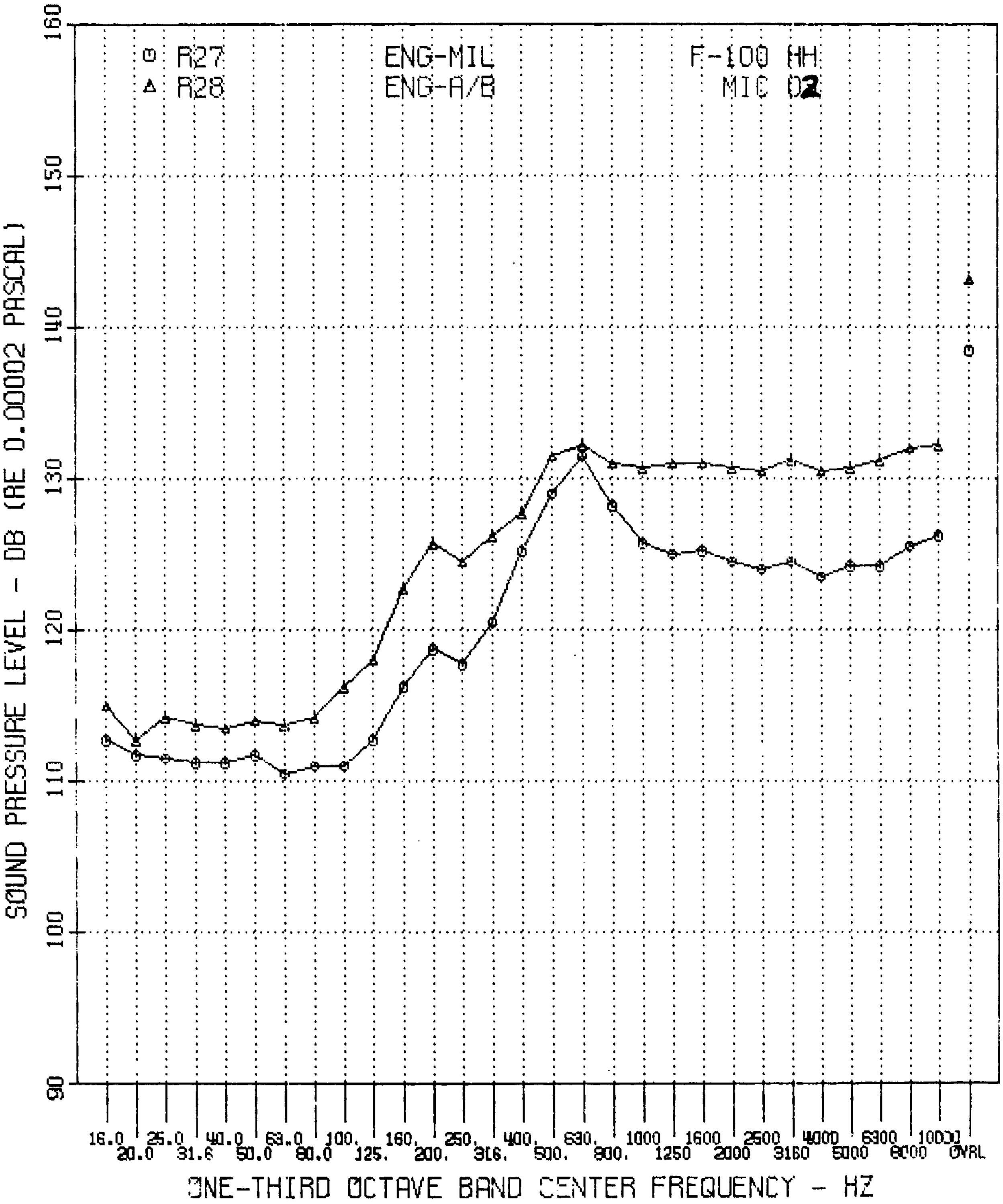


FIGURE B8 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 2.

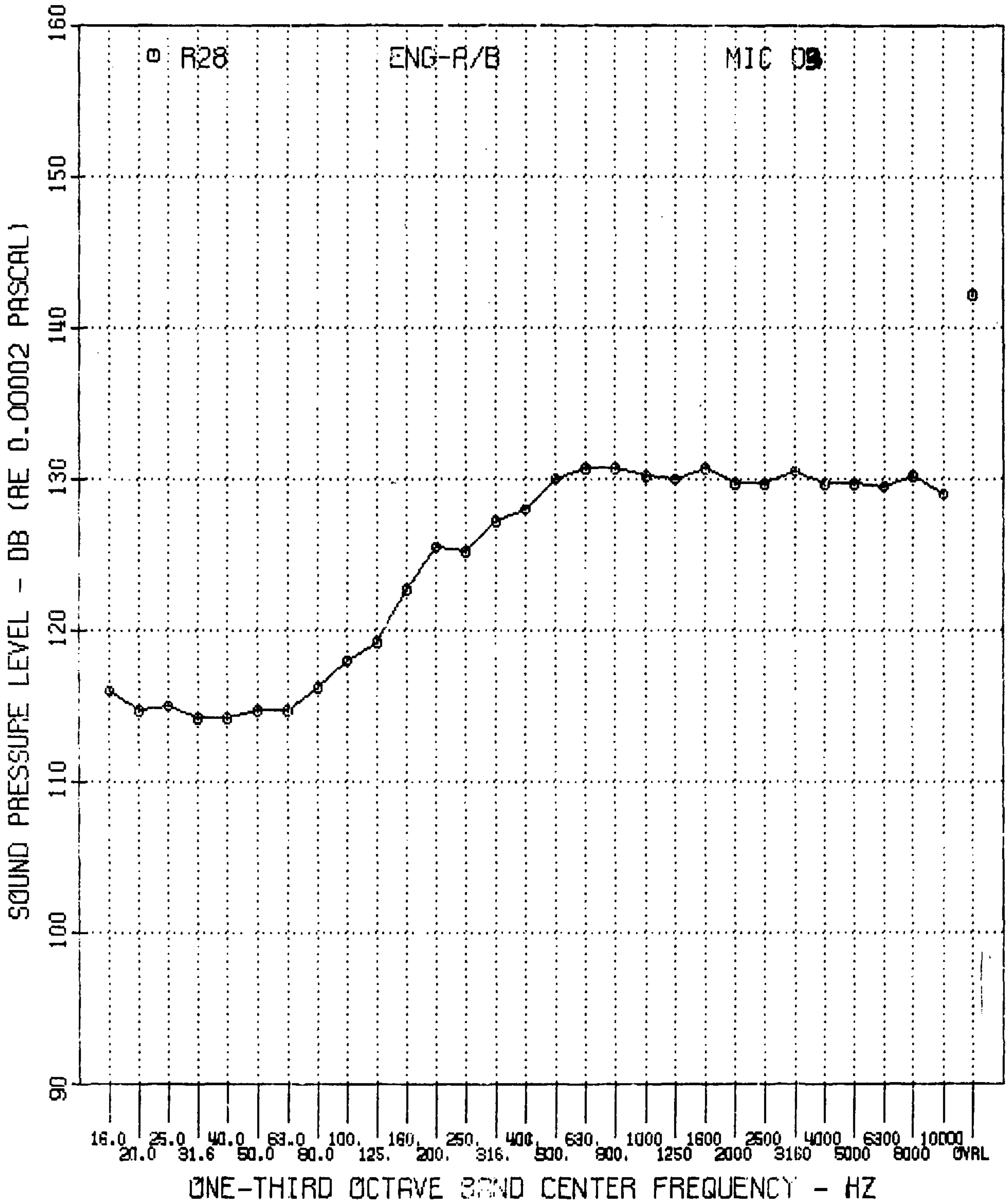


FIGURE B9 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 3.

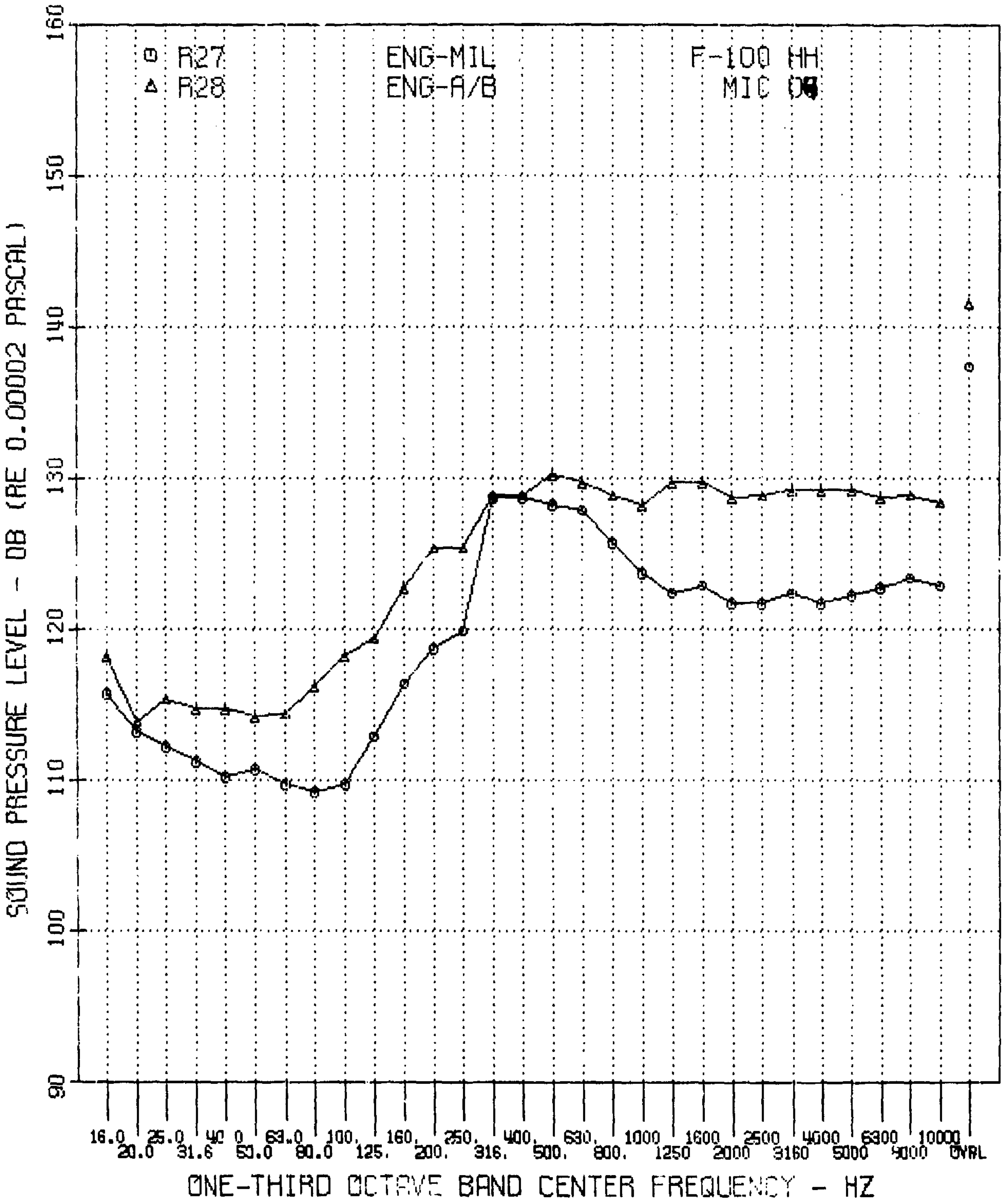


FIGURE B10 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 4.

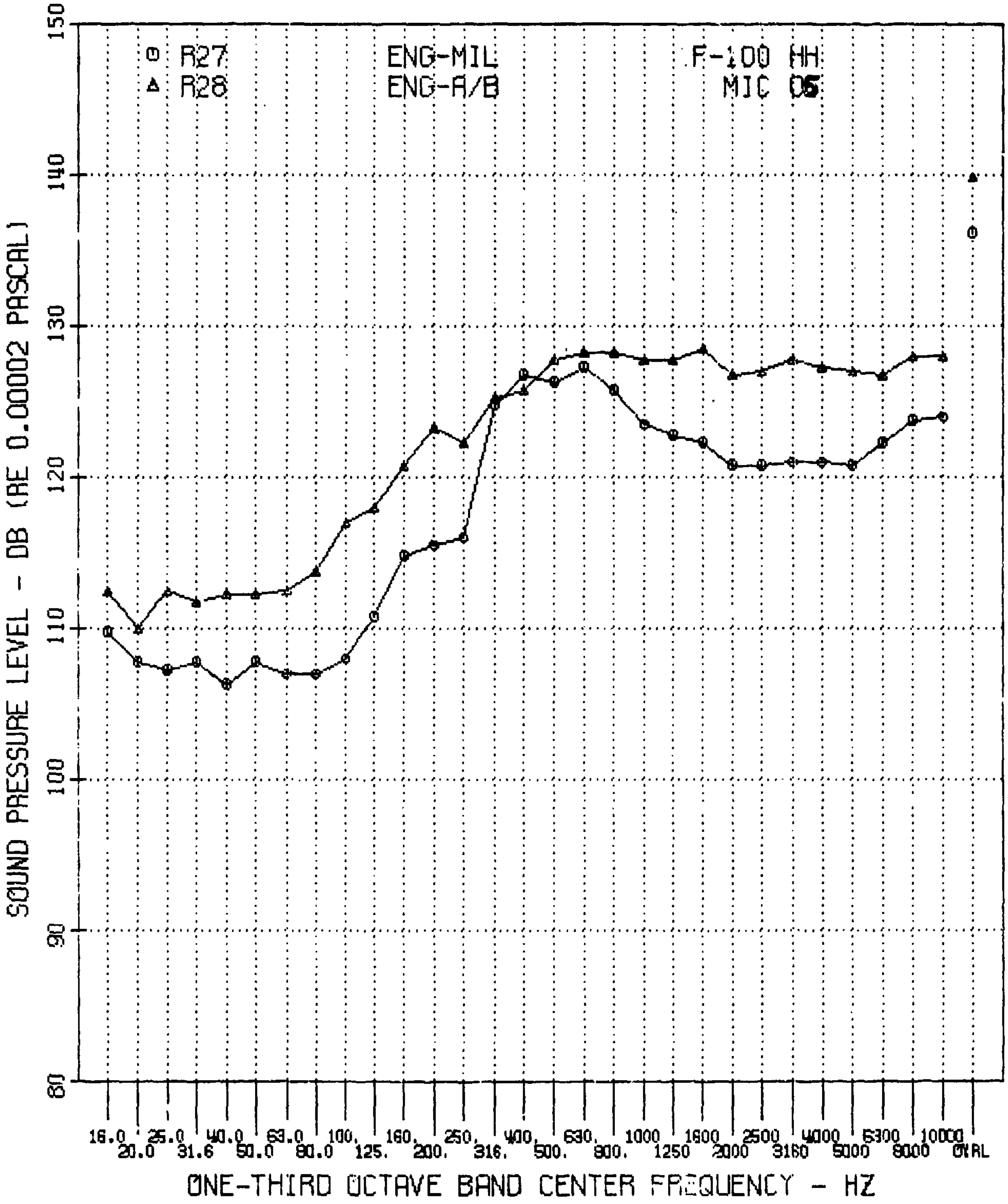


FIGURE B11 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 5.

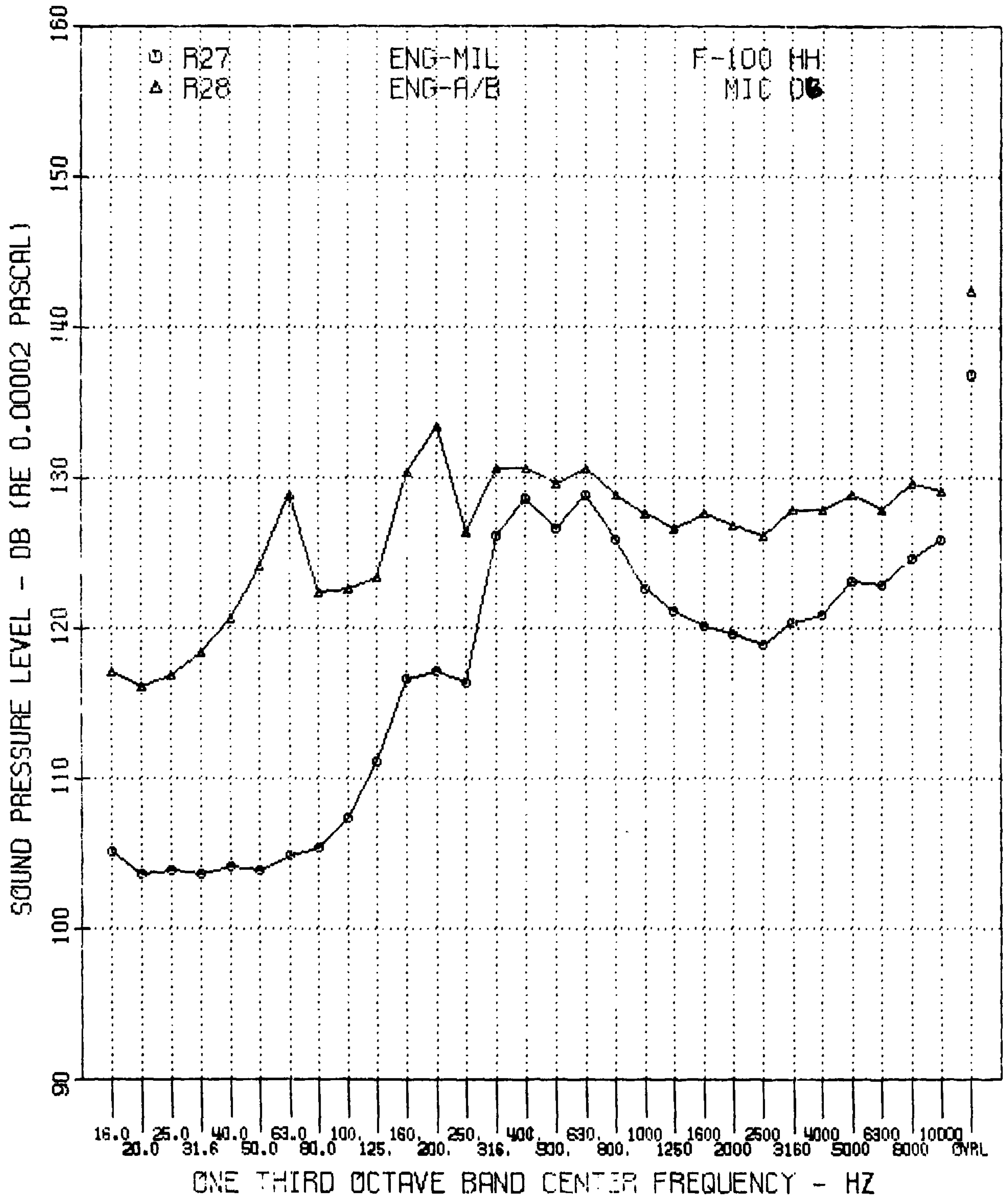


FIGURE B12 One-Third Octave Band Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 and 28 - Microphone 6.

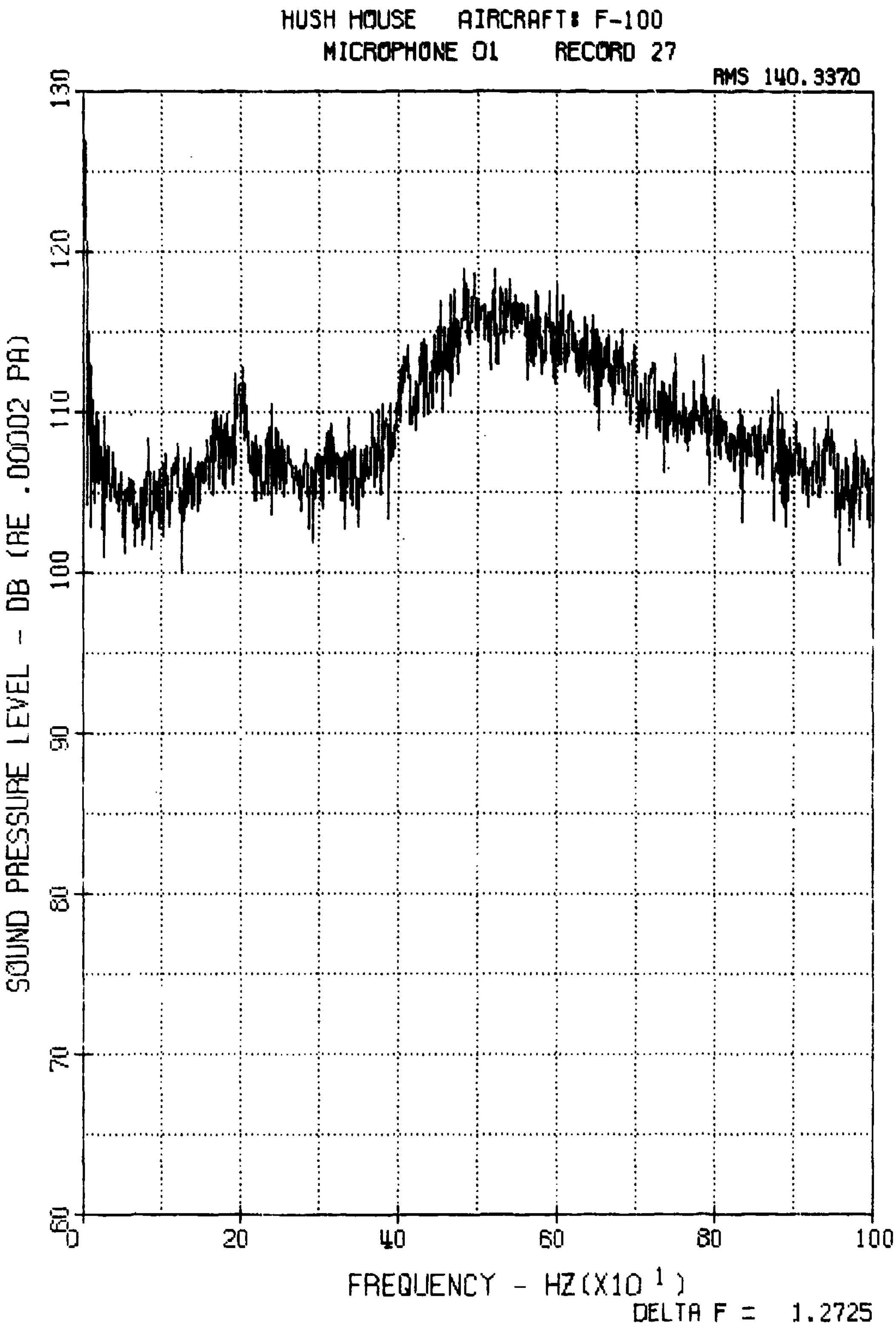


FIGURE B13 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 27 - Microphone 1.

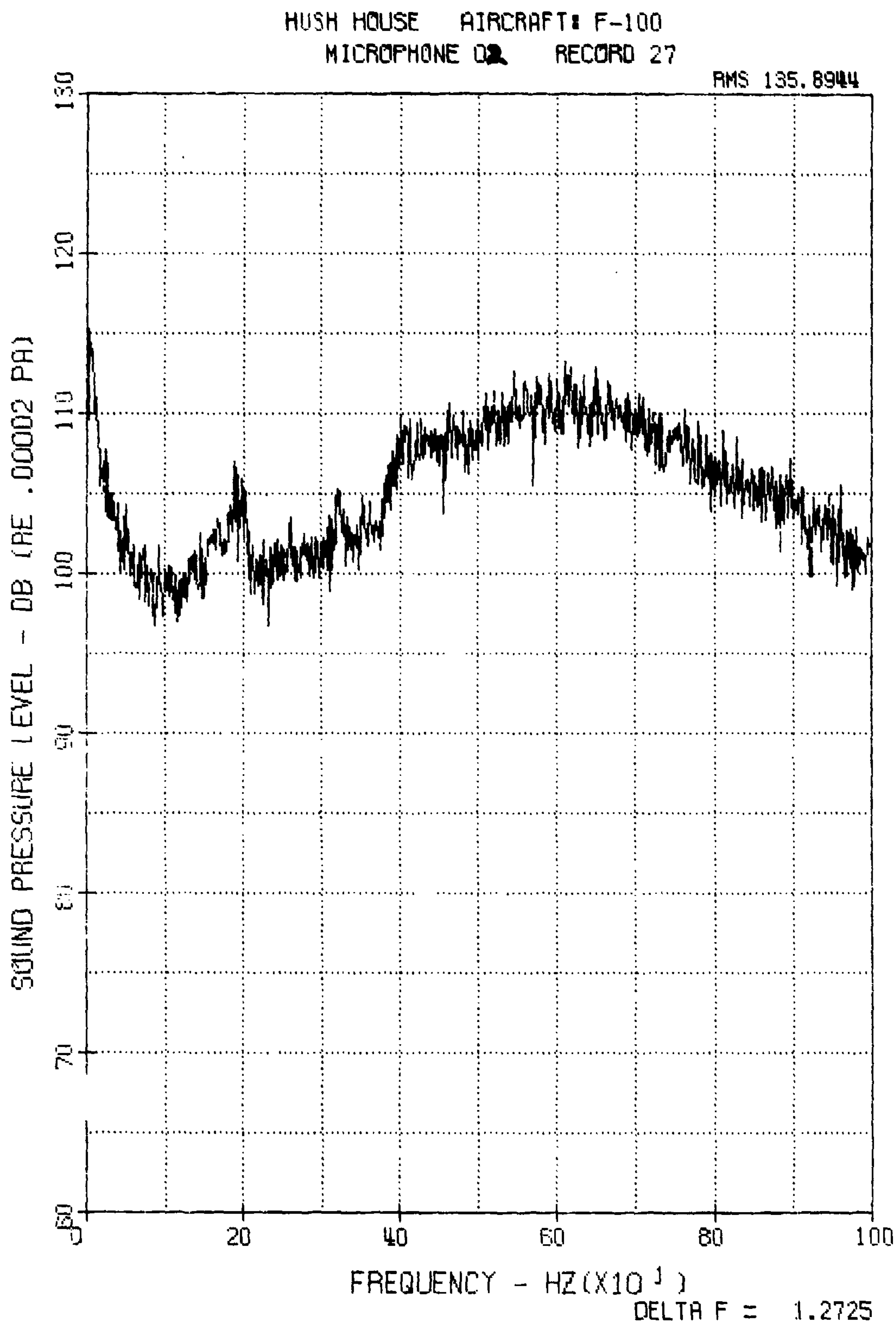


FIGURE B14 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 27 - Microphone 2.

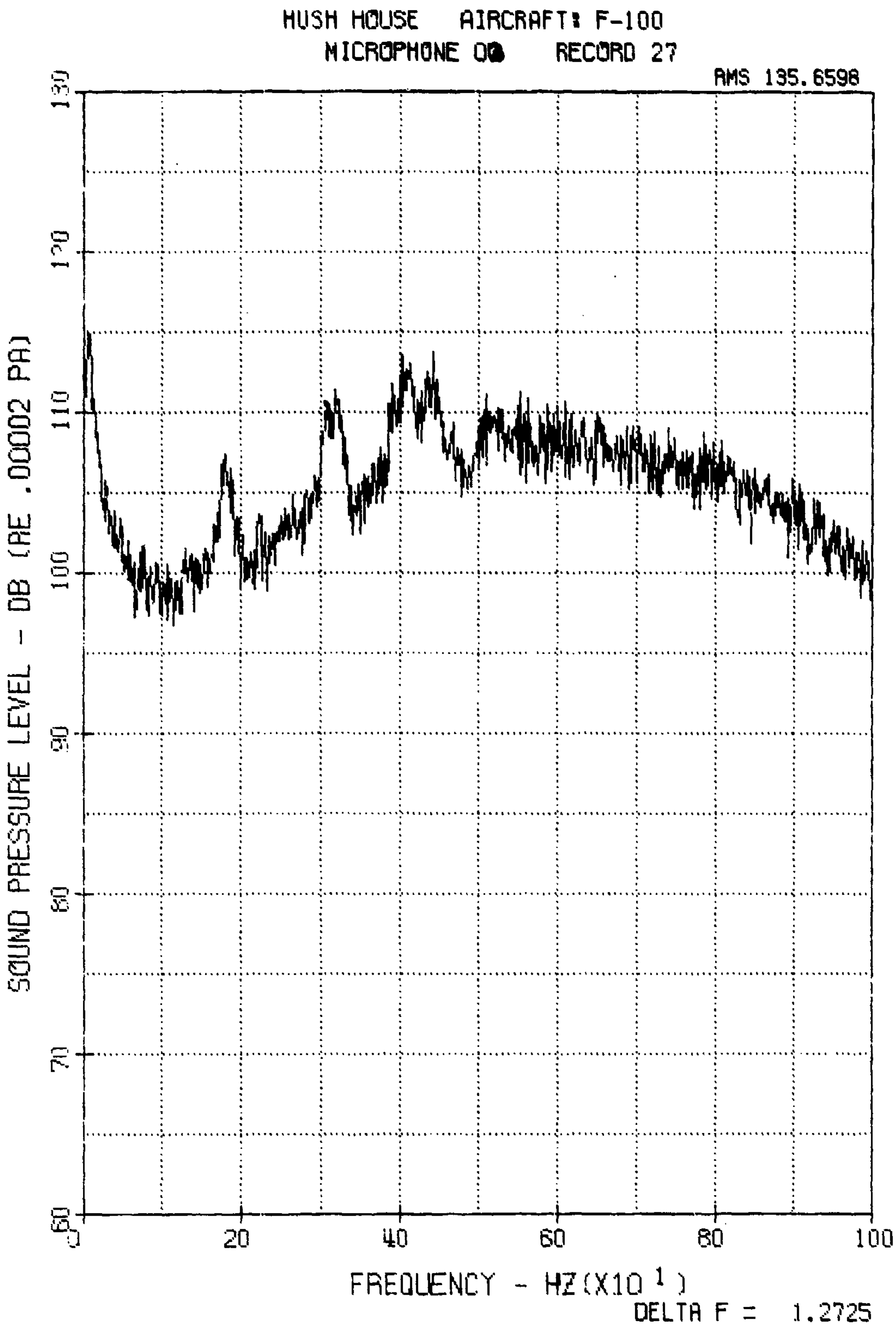


FIGURE B15 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 27 - Microphone 3.

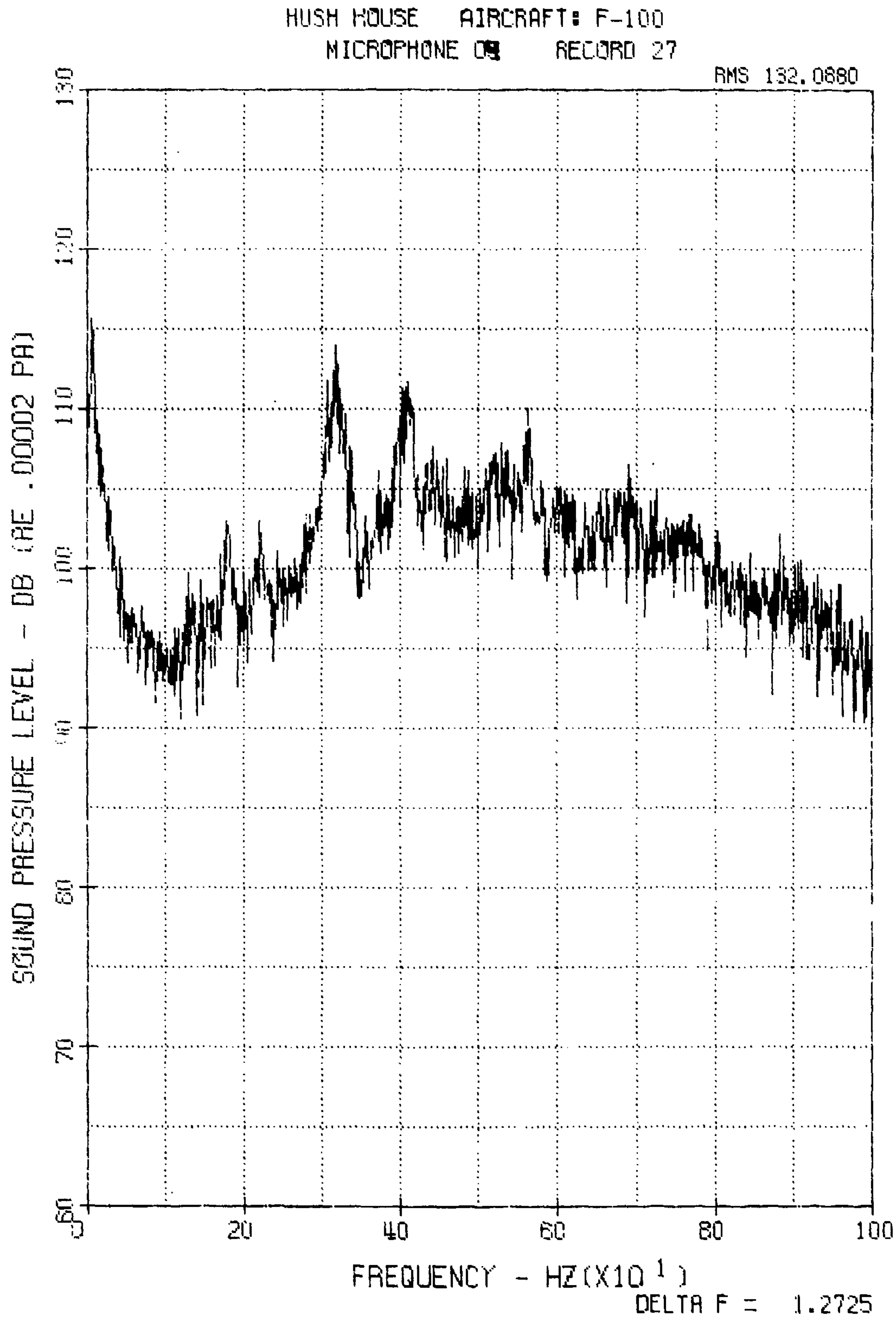


FIGURE B16 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 27 - Microphone 4.

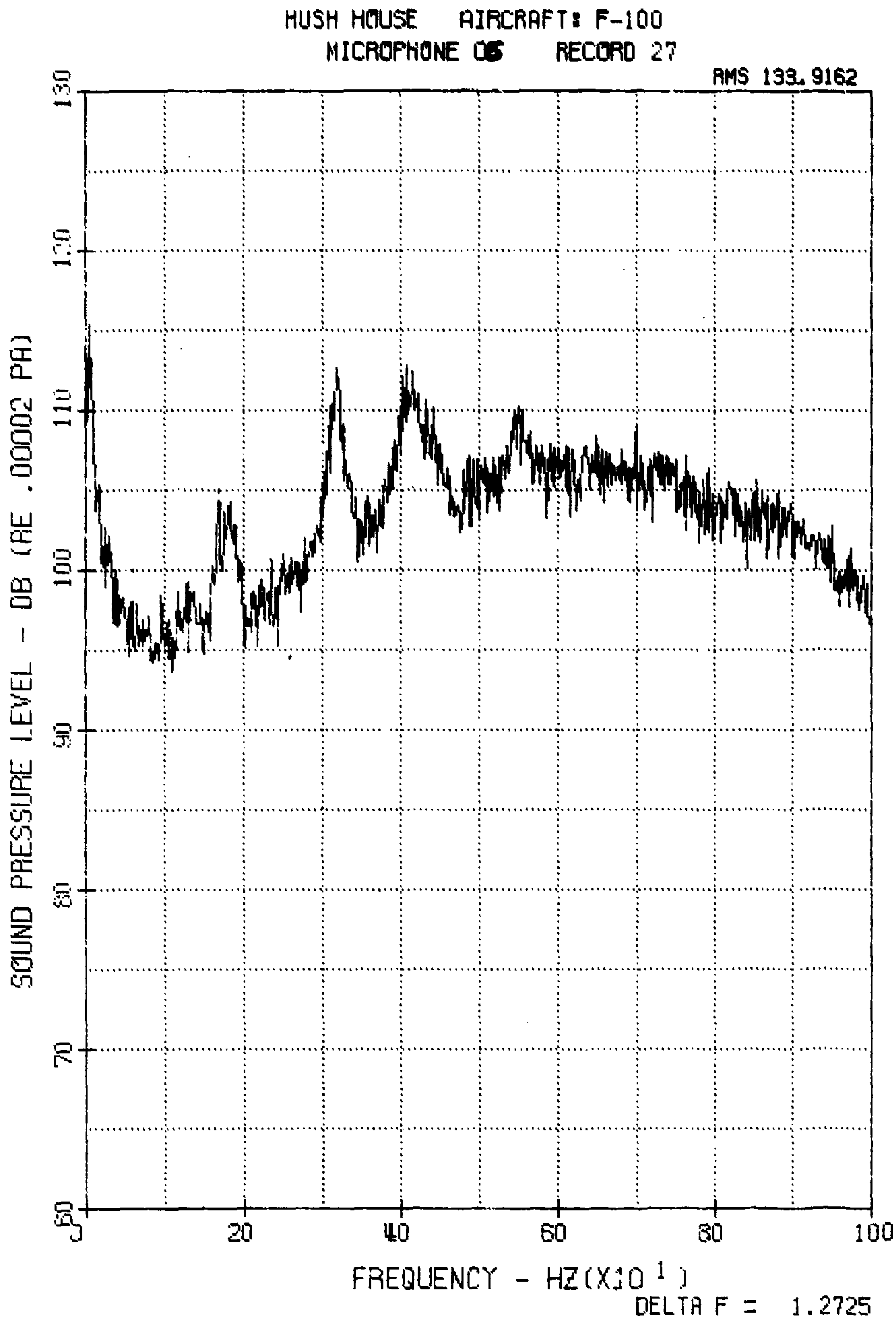


FIGURE B17 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Numbers 27 - "icrophone 5.

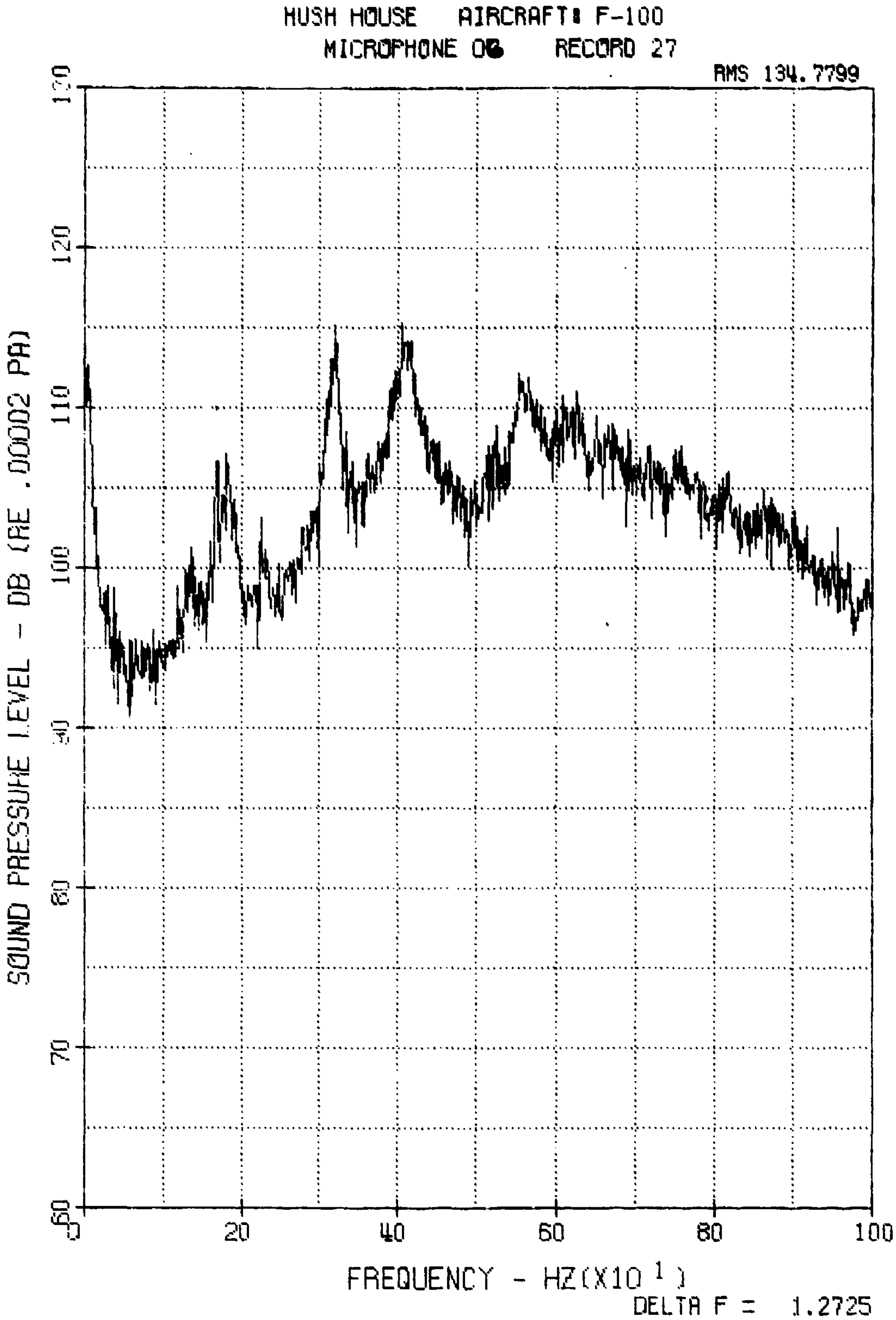


FIGURE B18 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 27 - Microphone 6.

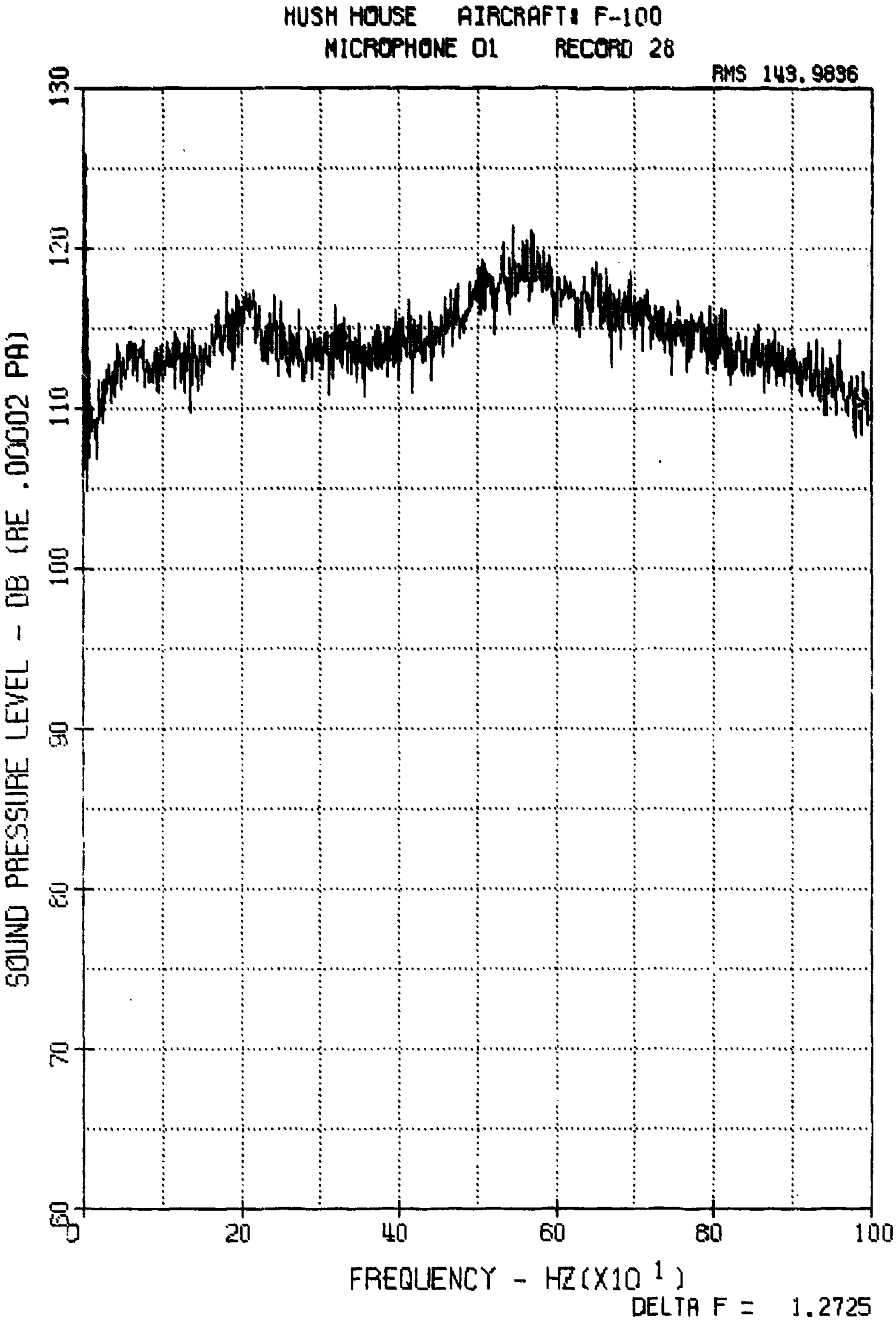


FIGURE B19 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 1.

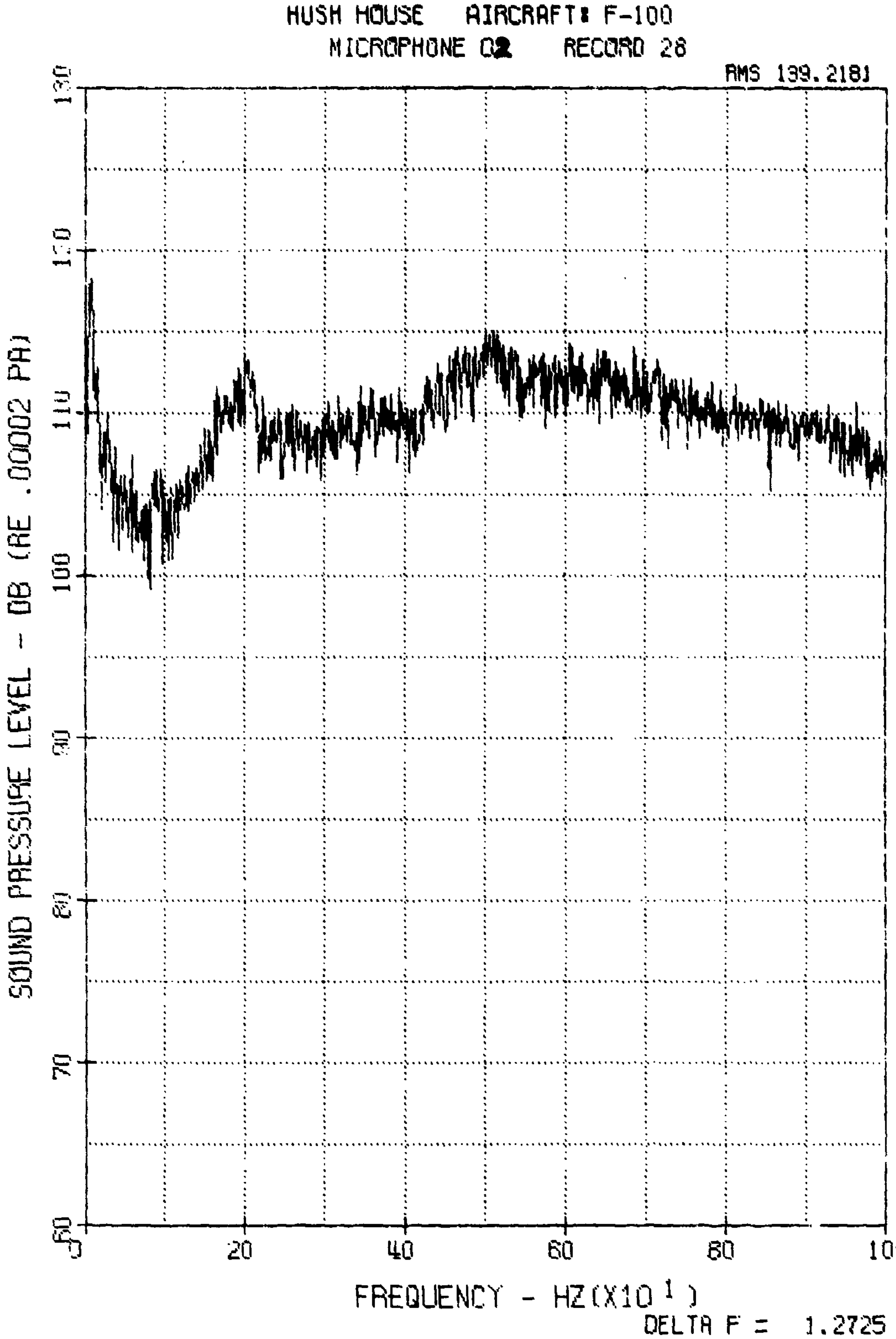


FIGURE B20 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 2.

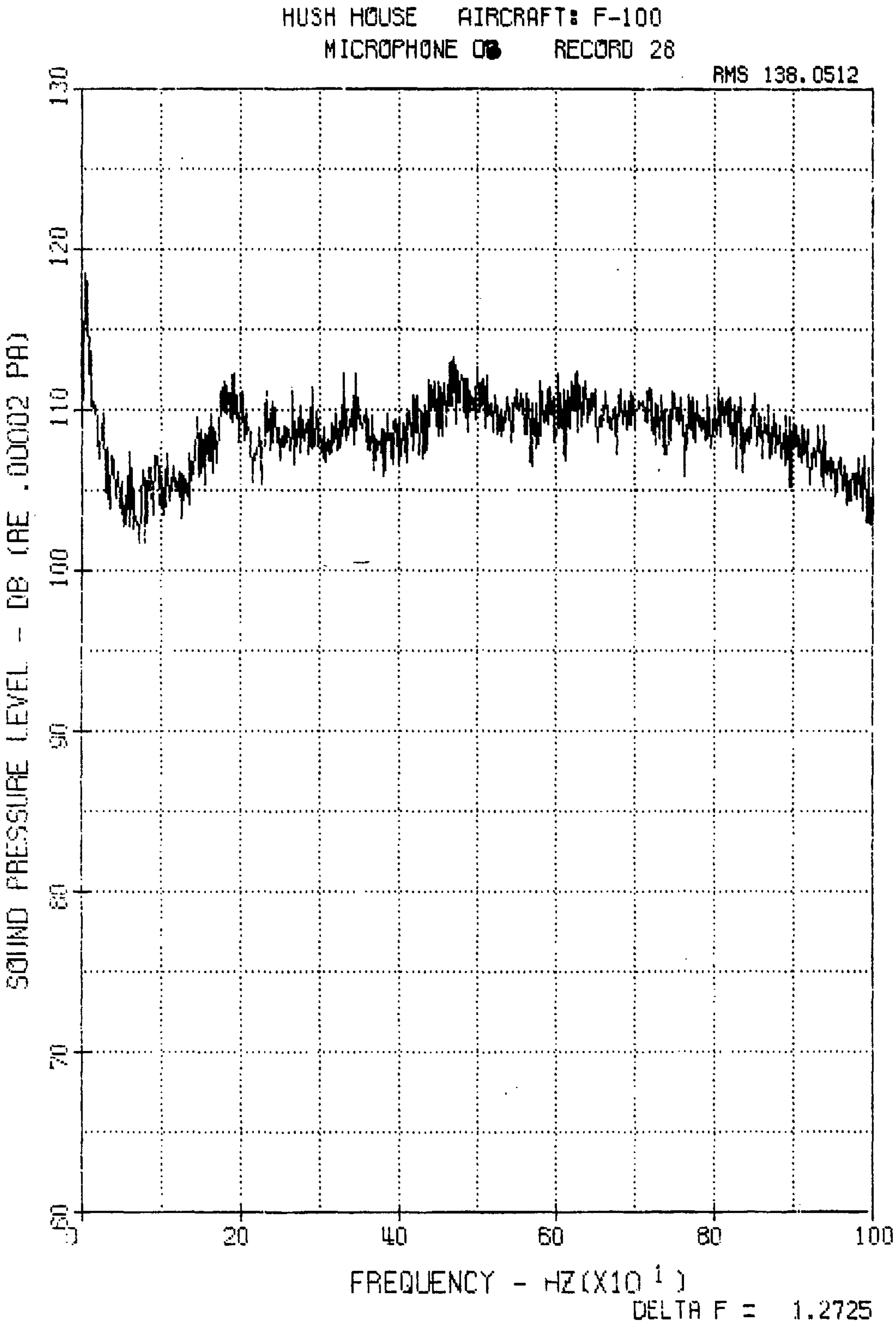


FIGURE B21 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 3.

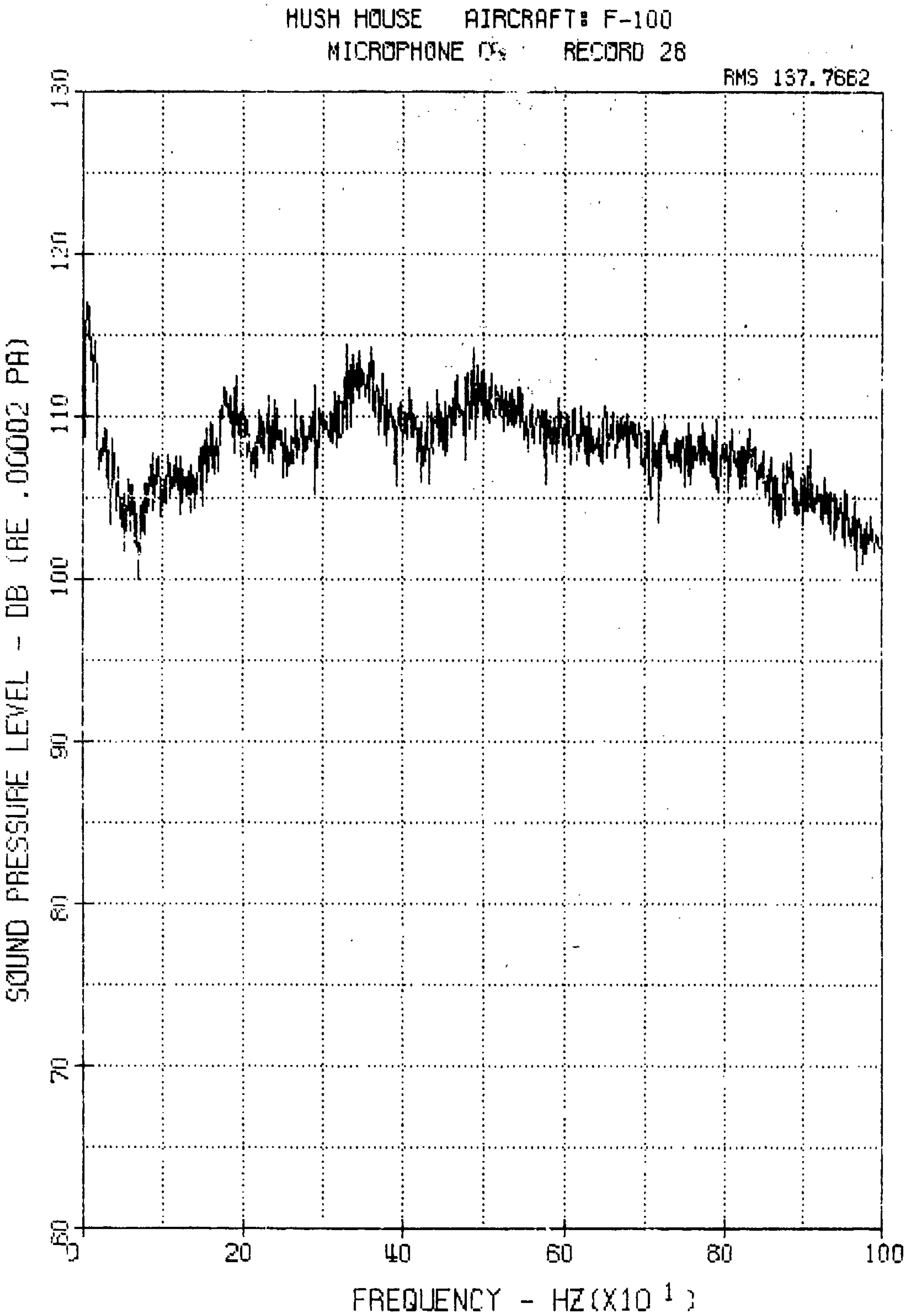


FIGURE B22 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 4.

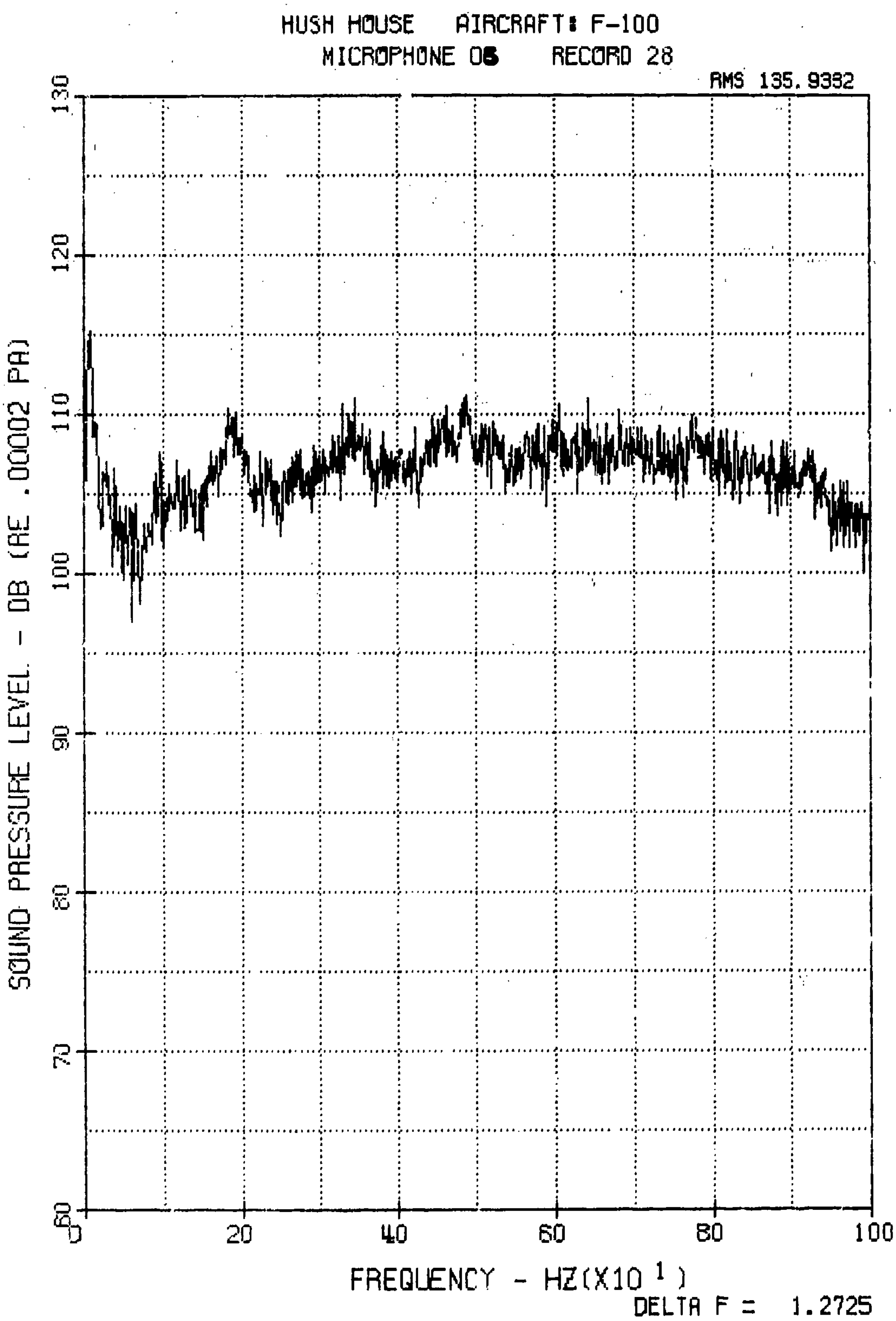


FIGURE B23 Narrowband (1.27 Hz) Spectra for F100-PW-100 Engine Installed in Hush House for Record Number 28 - Microphone 5.

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